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Microscopical Identification of Collected Aerosols

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The aerosol samples, collected by aircraft at elevations from 1,000 to 4,000 feet above sea level, consisted principally (more than 95 percent by number) of mineral silicate fragments. The silicates measured from less than 1 μm to approximately 10 μm in diameter. The particles size modes were 1-2 μm upwind of the city and 4-5 μm for sampling traverses downwind of the commercial and industrial areas. A trace to minor quantity of carbonaceous particles (resembling diesel exhaust), lead bromide compounds (from vehicle exhausts), and sea salt were also found in most samples. No discrete particles of ammonium sulfate were present.

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Microscopical Identification of Collected Aerosols

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This report was submitted in partial fulfillment of Grant R803078 by IIT Research Institute under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from July 1, 1974 to October 31, 1977, and work was completed as of June 15, 1979.

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SECTION 1

INTRODUCTION

An atmospheric pollutant study sponsored by the U.S. Environmental Protection Agency was conducted in Houston, Texas during July 1974 under the direction of Dr. James R. Brock of the University of Texas.[1] The purpose of that study was to gain preliminary information principally on the spatial and temporal distribution of primary aerosols and secondary aerosols and their precursors.

Aerosols were sampled and gaseous pollutants were monitored using an instrumented CESSNA 206 airplane operated by Meteorology Research, Inc. Wind speed and direction data were collected at a number of ground-based stations using pibals.[2] Additional meteorological data, including daily rawindsondes, were also used for predicting weather and for calculating pollutant flux.[1]

Sampling flights were usually made at right angles to the wind direction between two ground-level locations. Pollutant concentrations were measured by performing repeated traverses at various elevations (usually 1,000, 2,000, 3,000, and 4,000 feet) between the ground-level locations. This provided a cross-sectional concentration of pollutants which, when coupled with wind data, gave the pollutant flux.

The collected aerosol mass from each flight traverse was too small to measure gravimetrically; however, aerosol concentrations were measured with a condensation nuclei counter and an integrating nephelometer. In addition to aerosol measurements, the concentrations of CO, NO_x, SO_2, O_3, and gaseous hydrocarbons were measured during each flight.

A number of aerosol samples were selected for microscopical examination by IITRI to determine the identity and sources of aerosols upwind and downwind of Houston and also downwind of the industrial area east of Houston. These aerosol analyses could then be compared to the spatial and temporal concentrations of gaseous pollutants so that trends for the formation of secondary aerosols could be examined.

This report presents the results of microscopical analyses as a contribution to an understanding of Houston's urban pollutants.

SECTION 2

SAMPLE COLLECTION

Aerosol samples were collected on 0.8 μm pore size MILLIPORE membrane filters (type AA) at a sampling rate of 10-15 liters per minute through a 0.125 inch inlet tube. The aircraft flight speed ranged from 60 - 120 miles per hour during sampling.

Table 1 is a summary of samples that were analyzed microscopically. This is only a partial list of samples collected and flights made during the study. An explanation of the column title flight paths is presented in Section 4.

TABLE 1. SUMMARY OF AEROSOL SAMPLES ANALYZED MICROSCOPICALLY

Date	Sample No.	Flight Path	Start Time, CDT	Sampling Duration, min.	Elevation, ft.	Approx. Wind Direction at Elevation	Approx. Wind Speed at Alt., knots
19 July 1974	1	L to A	9:27	11	1000	WSW(1)	5-10
	2	A to L	9:47	11	2500	WSW	5-10
	3	L to A	10:01	10	3500	S	5-10
	4	A to L	10:14	10	4500	(2)	(2)
	5	L to A	10:31	10	1000	W	5-10
20 July 1974	6	M to Q	9:04	11	1700	W(3)	15-20
	7	V to W	10:26	49	1000	WNW(4)	5-10
					2000	WNW(4)	5-10
					3000	NW(4)	0-5
	8	H to D	13:44	35	1000	SW(5)	0-5
					2000	WSW(5)	0-5
					3000	NW(5)	5-10
					4000	NW(5)	5-10
21 July 1974	9	H to D	6:33	38	1000	SW(5)	15-20
					2000	SW(5)	10-15
					3000	SSW(6)	0-5
					4000	SE(5)	0-5

Notes: (1) wind speed and direction measured at Westbury H.S. and Hobby Airport pibal sites.
(2) data not available
(3) wind speed and direction measured at EMSU pibal site
(4) wind speed and direction measured at San Jacinto pibal site
(5) wind speed and direction measured at Hobby Airport pibal site

SECTION 3

SAMPLE PREPARATION

Each of the cellulose acetate membrane filters was examined with a stereomicroscope using reflected light to determine whether the collected aerosols were uniformly distributed over the filter surface. Particles were generally more heavily loaded in the center third of the filter, which typically occurs when the sampling tube inlet diameter is significantly smaller than the filter diameter.

Those filters sampled for approximately 10 minutes were so lightly loaded that it was difficult to judge whether particles were uniformly distributed. Therefore, pie-shaped radial segments were cut from the filters to ensure that a representative sample would be analyzed.

The filter segment for polarized light microscopy was mounted between a glass slide and glass coverslip. The mounting procedure consisted of adding several drops of immersion liquid (refractive index = 1.515) to a glass slide, placing the filter segment onto the puddle of immersion liquid, and, once the liquid had penetrated the filter, adding the coverslip. The immersion liquid serves the dual function of making the filter transparent and providing a reference refractive index for particle identification.

A second pie-shaped radial filter segment was cut for scanning electron microscopy (SEM). These segments were taped to glass slides and coated with a thin film ($\sim$15 nm) of carbon in a vacuum evaporator (pressure = 10^{-5} mm Hg). The carbon film provides a conductive layer that minimizes sample charging which interferes with image formation. The coated segment is then placed on an aluminum specimen stub and electrically grounded by placing a thin stripe of conductive paint from the edge of the filter onto the stub.

SECTION 4

SAMPLE DESCRIPTIONS AND MICROSCOPICAL RESULTS

This section presents microscopical results and brief descriptions of the sampling locations (Brock's report[1]) and weather conditions (Hoffnagle's report[2]).

The results are presented for each sampling day and flight traverse. The integrated results for the entire experiment are presented in Section 5, Discussion of Results.

FRIDAY, 19 JULY 1974

Sampling Plan and Weather Conditions

Sampling was conducted west (upwind) of Houston's commercial and industrial areas to obtain background aerosol samples. The sampling flight paths were approximately at right angles to the wind directions. Five membrane filter samples were collected at various elevations along a flight path from points L to A (Figure 1). The aerosol samples collected during this flight are shown in Table 1.

At 1000 CDT, there was a general pattern of winds from the west and southwest at 5-10 knots. The inversion layer was at about 2,000 ft when measured at 0700 CDT by rawindsonde. At the time of sampling, however, all the samples were believed to have been collected in the mixing layer.

Microscopical Results--

All of the samples collected on Friday, 19 July 1974, had very low concentrations of aerosols (Figures 2-5). Almost all the particles were mineral fragments; very few were carbonaceous aerosols and even fewer, if any, ammonium sulfate particles. Most particles were smaller than 5 μm in diameter, with a modal size of 1-2 μm.

Scanning electron microscopy (SEM) confirmed the low concentration of aerosols on the filter. Energy dispersive x-ray microanalysis also showed that many of the aerosols were mineral silicates. Representative scanning electron micrographs are shown in Figures 6-27.

Unusual spheroids, measuring between 0.5 μm and 3 μm in diameter, were found in samples 1 through 5 (Figures 6, 7, 14, 15, 16, and especially 10 and 11). Based on their microscopical morphology, the spherical particles were part of the membrane filter and were not atmospheric aerosols. X-ray

microanalysis of the spheres gave a spectrum without any detectable elements. Some of the spheres began to degrade (thermally) during the x-ray microanalysis, suggesting that they were carbonaceous. Polarized light microscopy showed no discrete, black, opaque particles in the 0.5 μm to 3 μm range that could be carbonaceous combustion products. In fact, these particles could not be detected by optical microscopy on an oil-immersed filter segment, indicating that the particles are isotropic and match the refractive index of the oil and the filter. There are very few atmospheric aerosols that fit this morphology.

Also found in samples 1 through 5 were micro whiffle balls--atmospheric aerosols shown in Figures 23 and 24--which generally cluster by hundreds to form a spherical cage. They are black and opaque and presumed to be carbonaceous because they contain no elements detectable by x-ray microanalysis. They are most unusual in that they are monodisperse, 0.4 μm in diameter, and have a complex, symmetrical skeleton that is also a spherical cage.

These particles have been detected in aerosol samples from St. Louis, Miami, and the iron range in northern Minnesota. They are believed by one of the authors (RGD) to be ancient spores that are present in and emitted from diesel fuel. Micro whiffle balls always seem to occur as agglomerates and therefore do not act independently as light-scattering aerosols. Despite their large numbers they probably contributed very little to the b scat measured with the integrating nephelometer.

SATURDAY, 20 JULY 1974

Sampling Plan and Weather Contributions

Pollutant concentrations upwind of Houston (L to A), downwind of the commercial area (H to D), and downwind of the commercial and industrial areas (V to W), Figure 28, were made during morning and afternoon flights. (The upwind cross-section flight, L to A, is not shown since the sample was not analyzed microscopically.) A traverse was also made in the wind direction (M to Q). Samples 7 and 8 were used for multiple flights at varying elevations along the same path, as shown in Table 1.

The morning winds were principally from the west, whereas the afternoon winds shifted to the north and became calmer.

Microscopical Results--

Sample 6 showed about the same particle concentrations (Figure 29) as seen for samples 1 through 5. Samples 7,8 and 9, which were used for sampling periods approximately four to six times longer than sample 6, show correspondingly greater particle concentrations. Again, the dominant particle types collected on samples 7,8 and 9 were minerals (Figures 30-33). The mineral particles of the commercial and industrial areas collected downwind (samples 7 and 8) had a larger particle size than those collected upwind of Houston. These downwind minerals had a modal size of 4-5 μm, suggesting that these minerals were injected from Houston rather than merely transported from rural areas upwind of Houston.

The principal aerosol addition to sample 8, collected downwind of the Houston commercial area, was minerals, with a slight though trivial addition of lead compounds and carbonaceous agglomerates from vehicle exhausts.

SUNDAY, 21 JULY 1974

Sampling Plan and Weather Conditions

The sampling plan was similar to that of 20 July 1974. Two flight paths were flown: one downwind of the commercial area, the other downwind of the industrial area. The only sample analyzed microscopically was from the urban, downwind, commercial area (Figure 68). Sampling data for this flight are shown in Table 1.

The winds were principally from the southwest during sampling. An inversion layer was found at approximately 1200 feet at 0700 CDT, but no independent sample was collected above and below the inversion layer.

Microscopical Results--

The particles found on this filter were mainly mineral fragments with an estimated modal particle size of 4-5 μm, similar to those collected on 20 July 1974. Besides the minerals, there were traces of carbonaceous particles and lead-containing particles from vehicle exhausts.

SECTION 5

DISCUSSION OF RESULTS

The aerosol collected upwind and downwind of Houston and downwind of the industrial area (ship channel) were remarkably similar in composition. In every sample, minerals comprised more than an estimated 95% of the particle types by number. The remaining particles ranges from sea salt to carbonaceous deposits (mainly diesel emissions) and lead bromides (from vehicle exhausts). Whereas a few minerals contained minor x-ray fluorescence peaks for sulfur, there were no discrete particles of ammonium sulfate, commonly found in urban aerosols.

Two points are worthy of further discussion. First, high ozone concentrations (0.2 ppm) were noted in the presence of (relatively high b scat values ($\sim 5 \times 10^{-4} m^{-1}$) above the mixing layer.[1] While the high b scat values appear due to the mineral particles, secondary aerosols may have been present also. These secondary aerosols were not detected microscopically, suggesting that they may have been present as liquids.

Secondly, a greasy deposit was reported to have formed on the airplane wings. The deposit was heavy enough to require washing the airplane after every two days of sampling. Some of this grease or thick oil would be expected on the membrane filters, but none was found on any of the filters, even those downwind of the industrial area.

The absence of grease on the filters may be linked to sampling bias. The grease particles that accumulated on the wings may have been larger than 10 μm in diameter. Since the inlet tubing had a diameter of only 1/8 inch, the grease particles would never reach the filter. Alternately, the grease particles may have been not only large but also few in number. Spread on the wing, they may have looked more abundant than was actually the case.

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2. Hoffnagle, G.F. Air Pollution Meteorology During the Houston Urban Plume Study, July 1974. EPA-600/3-77-073, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1977. 63 pp.

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59 SEXM of rounded mineral grain showing peaks for Na, Mg, Al, Si, P, S, Cl, K, Ca, and Fe. The nearby mineral grains are also contributing to the spectrum 46

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65 Back scattered electron image to detect heavy metals, especially lead in sample no. 8. The five small, very bright dots that are circled are lead compounds from auto exhaust; 500X 49

66 SEMG of lead chloro bromide particle marked A adjacent to a mineral fragment of sample no. 8; 10,000X. 49

67 SEXM of lead chloro bromide particle in Figure 66 showing peaks for Al (01.5 Kev), Si (01.7 Kev), Pb (02.3 Kev), Cl (02.6 Kev), K (03.3 Kev), Ca (03.7 and 04.0 Kev), Fe (06.4 Kev), Pb (10.5 and 12.6 Kev), and Br (11.9 Kev). All the peaks but Pb, Cl and Br are from the mineral cluster adjacent to particle A . . . 50

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69 SEMG of sample no. 9, showing area with greatest aerosol concentration (of minerals); 100X. 52

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74 SEMG of artifact spheres in sample no. 9; 3,000X 54

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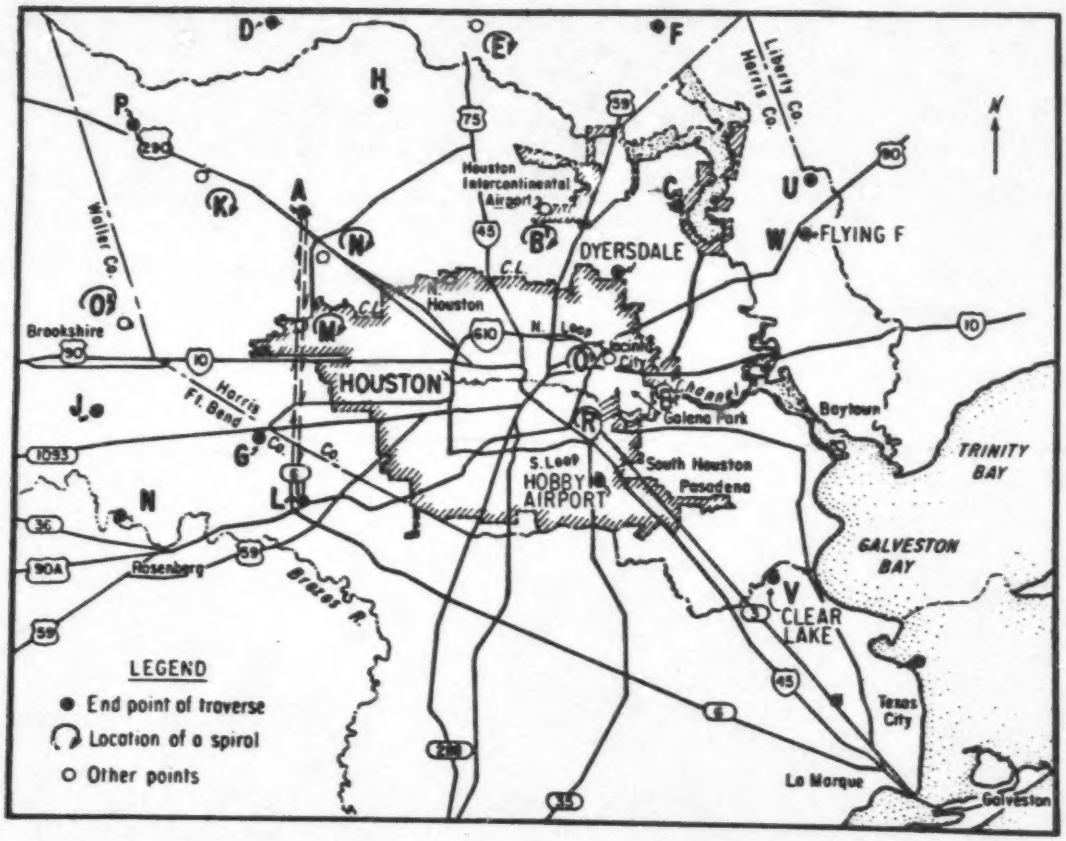

Figure 1. Flight path for 19 July 1974 sampling mission.

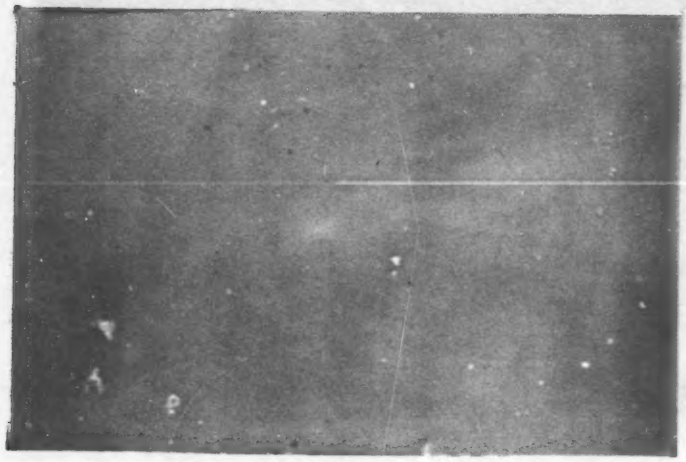

Figure 2. Photomicrograph of sample no. 1, showing very light loading of mineral fragments (bright); polars uncrossed 10°, 406X.

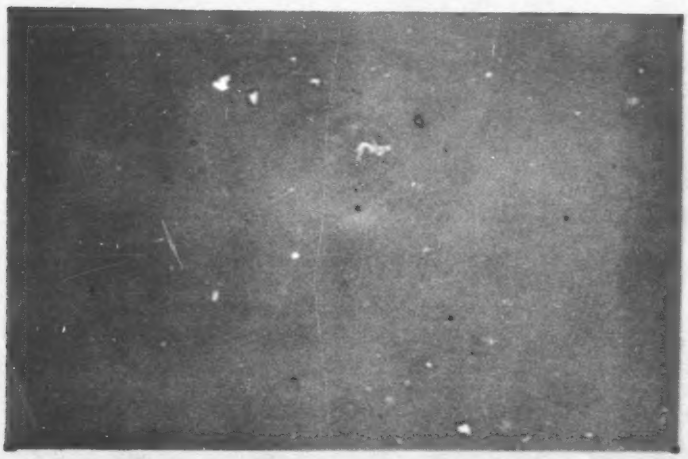

Figure 3. Photomicrograph of sample no. 2, showing very light loading of minerals and some iron oxides; polars uncrossed 10°, 406X.

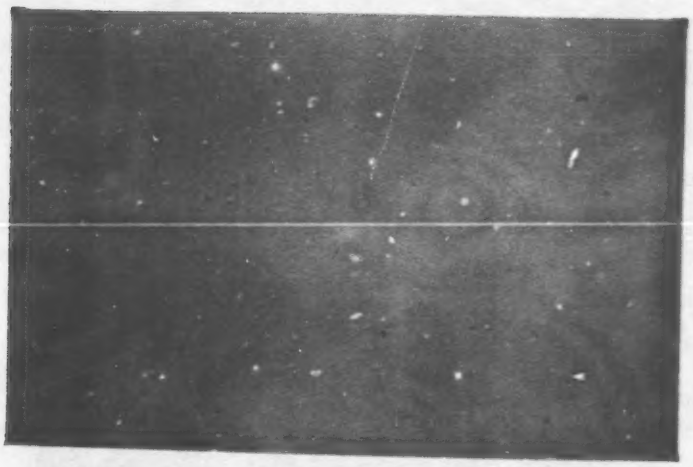

Figure 4. Photomicrograph of sample no. 3, showing a light loading (though heavier than samples 1 or 2) of minerals; polars uncrossed 10°, 406X.

Figure 5. Photomicrograph of sample no. 4, showing mineral particles; crossed polars, 406X.

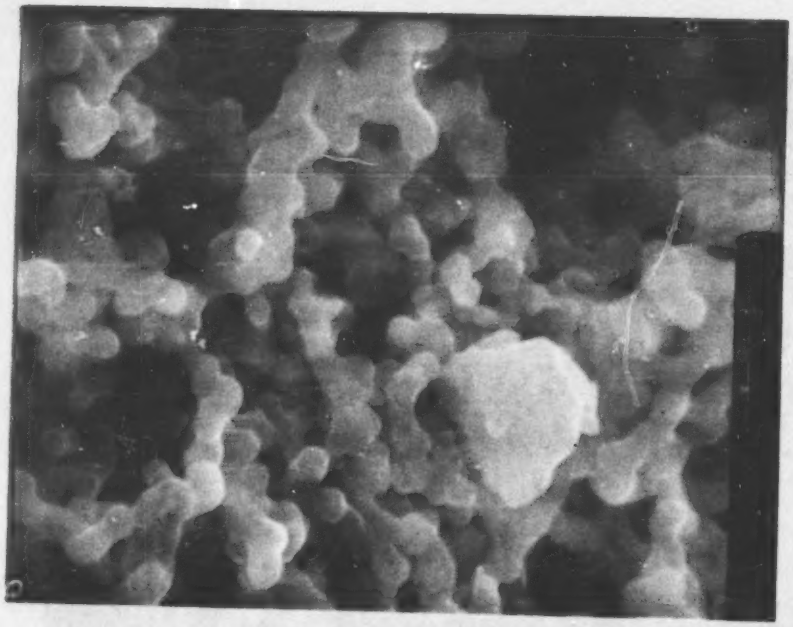

Figure 6. Scanning electron micrograph (SEMG) of 2 μm diameter mineral fragment on sample no. 1 containing silicon, aluminum, potassium and iron; 10,000X.

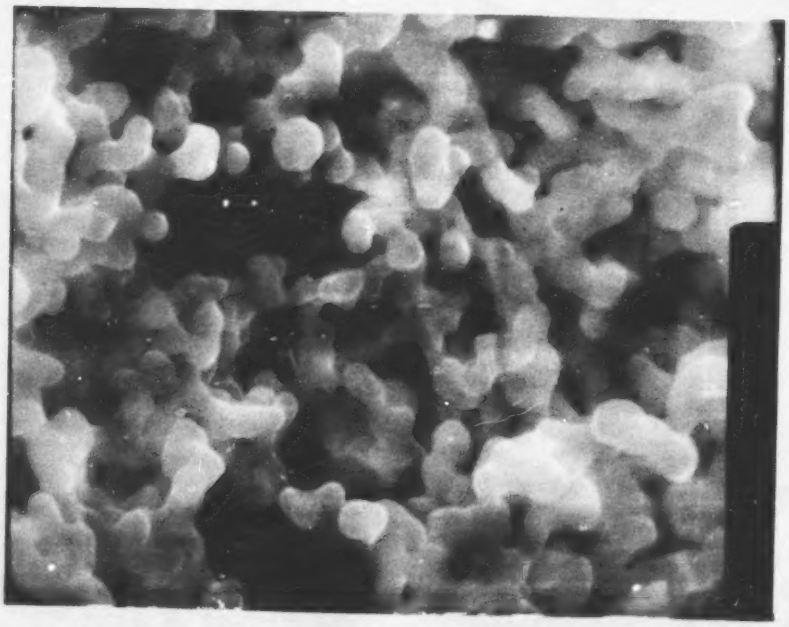

Figure 7. SEMG of typical field of view for sample 1 showing an abscence of particles away from the filter center; 10,000X.

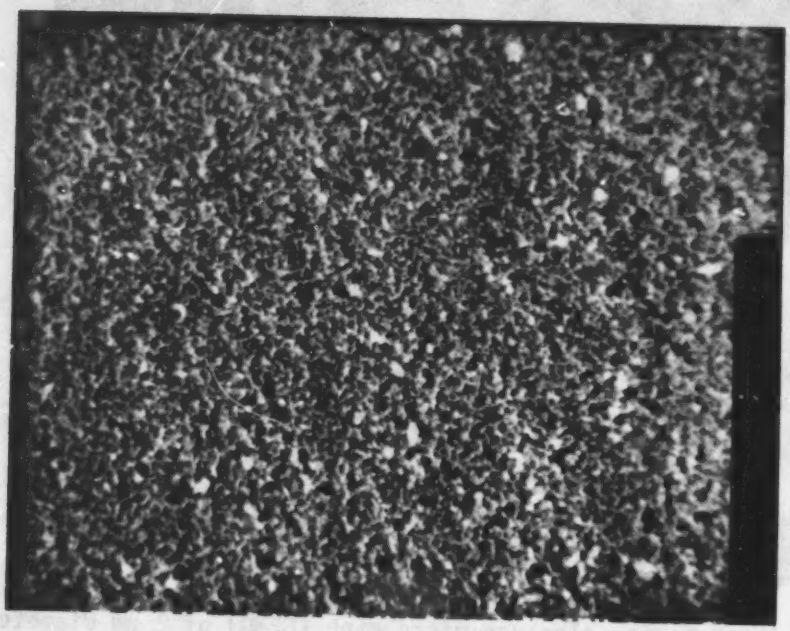

Figure 8. SEMG of sample no. 2 showing the area of greatest aerosol concentration; (the bright spots); 500X.

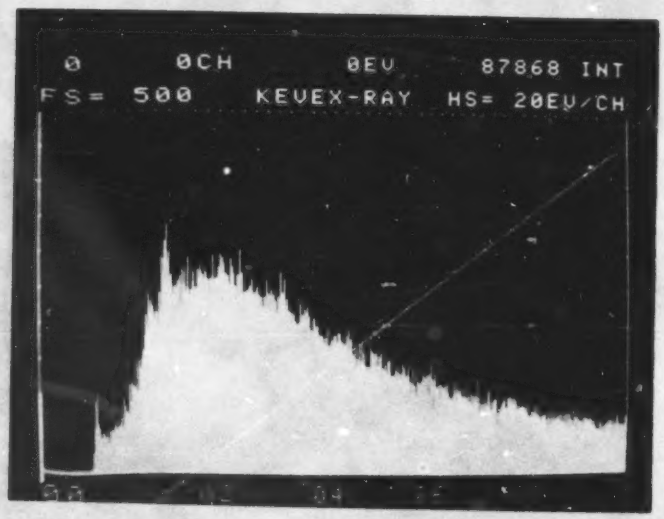

Figure 9. Scanning electron x-ray microanalysis (SEXM) of area in Figure 8, showing a very weak spectrum for aluminum and silicon, which corroborates the low aerosol concentration.

Figure 10. SEMG of sample no. 2, showing apparent spherical particles that are actually part of the membrane filter structure; 3,000X.

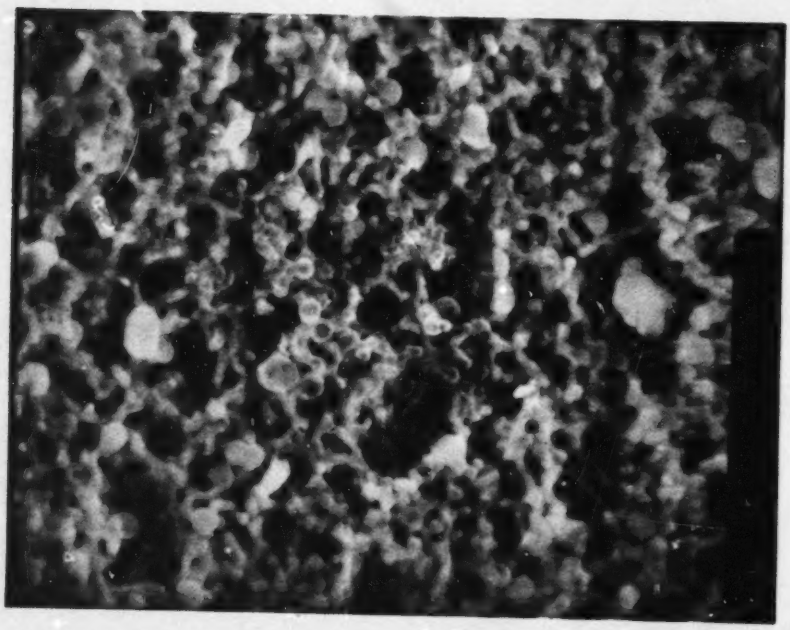

Figure 11. Same as Figure 10, except that the electron beam was rastered over the central portion of the area that caused some thermal degradation of the membrane polymer; 3,000X.

Figure 12. SEMG of sample no. 3, showing low concentration of aerosols; 500X.

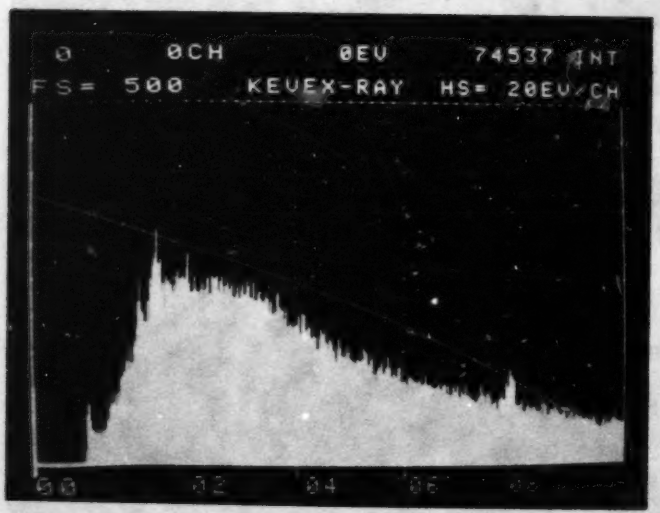

Figure 13. SEXM of area in Figure 12, showing peaks for aluminum, silicon and copper.

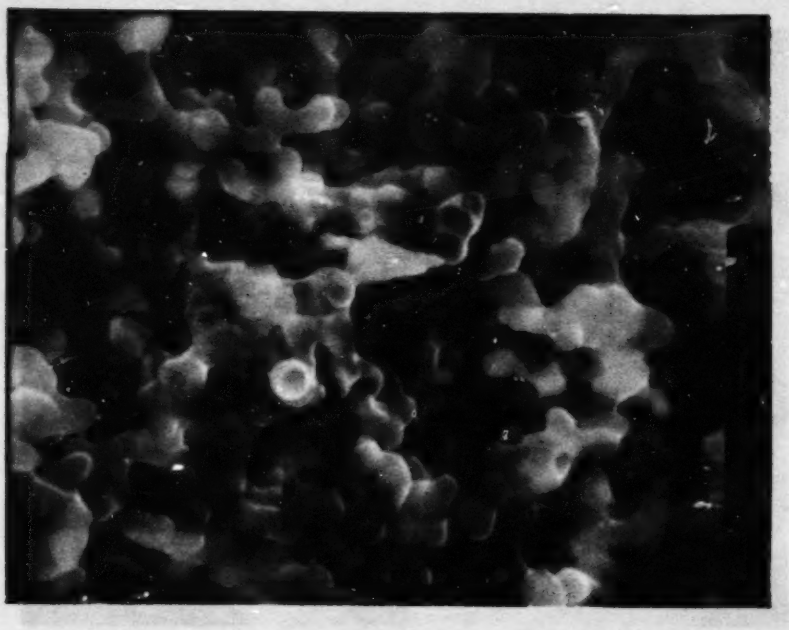

Figure 14. SEMG of sample no. 3, showing membrane filter structure and triangular mineral fragments near the center; 10,000X.

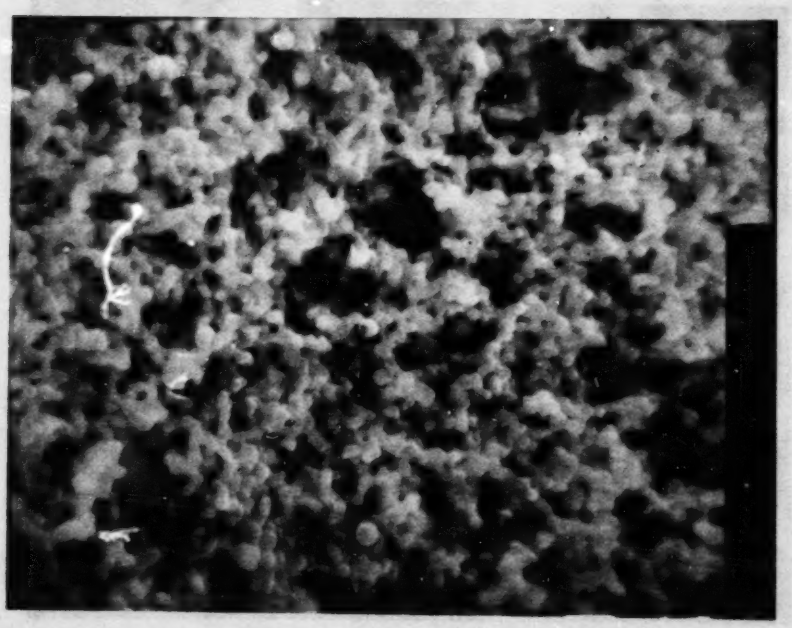

Figure 15. SEMG of sample no. 4, showing a low aerosol concentration and the artifact spherical aerosols that are part of the membrane structure; 3,000X.

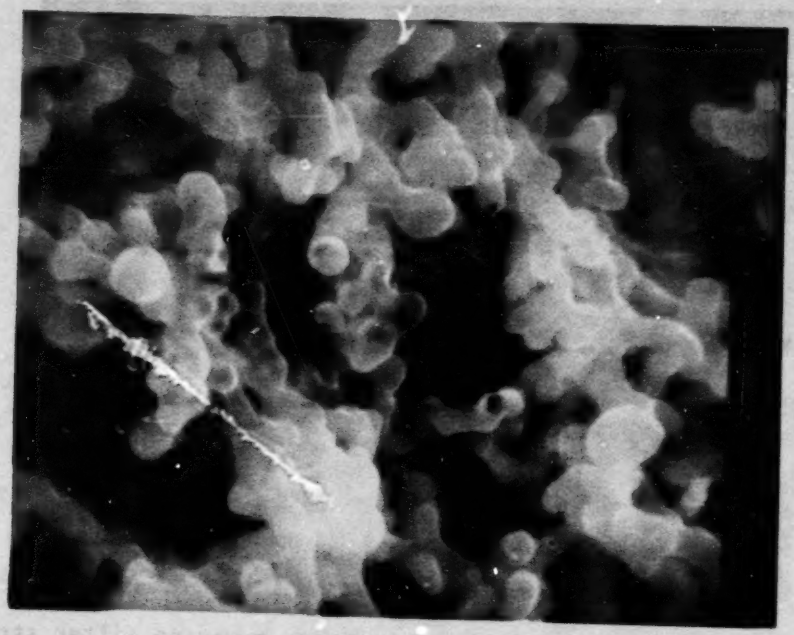

Figure 16. Same as Figure 15, but at higher magnification; 10,000X.

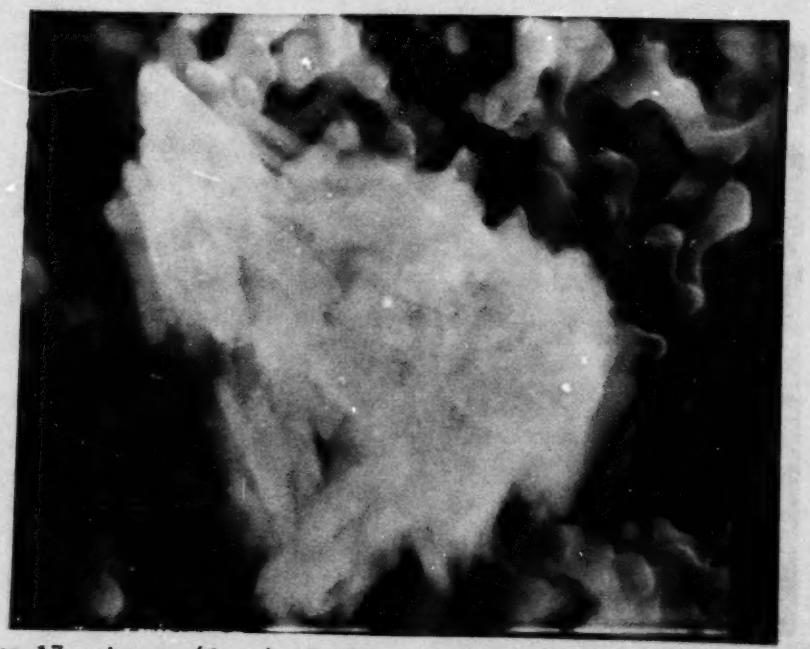

Figure 17. Large (8 μm) cluster of calcium sulfate crystals on sample no. 4, probably formed from sulfuric acid attack of calcium carbonate; 10,000X.

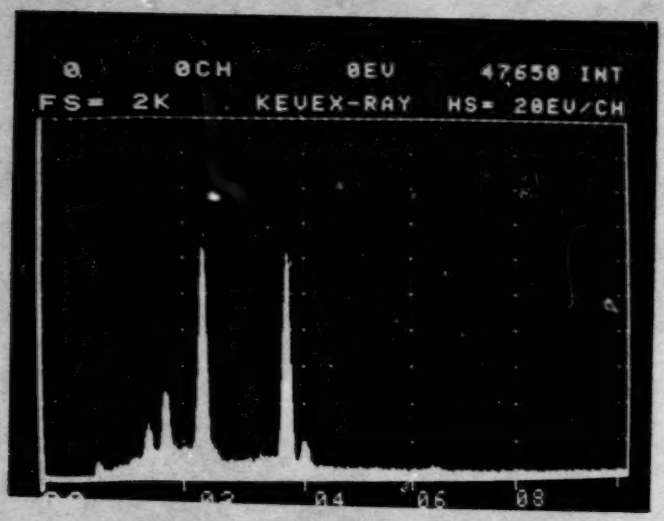

Figure 18. SEXM of large cluster in Figure 17, showing peaks for Mg (01.3 Kev), aluminum (01.5 Kev), silicon (01.7 Kev), sulfur (02.3 Kev), and calcium (03.7 and 04.0 Kev).

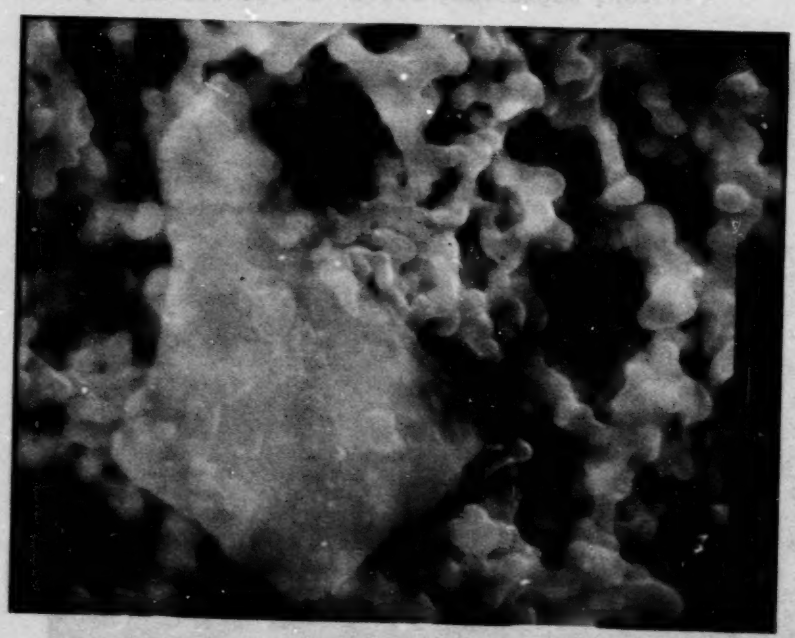

Figure 19. SEMG of 10μm mineral flake containing silicon, aluminum and calcium; 8,000X.

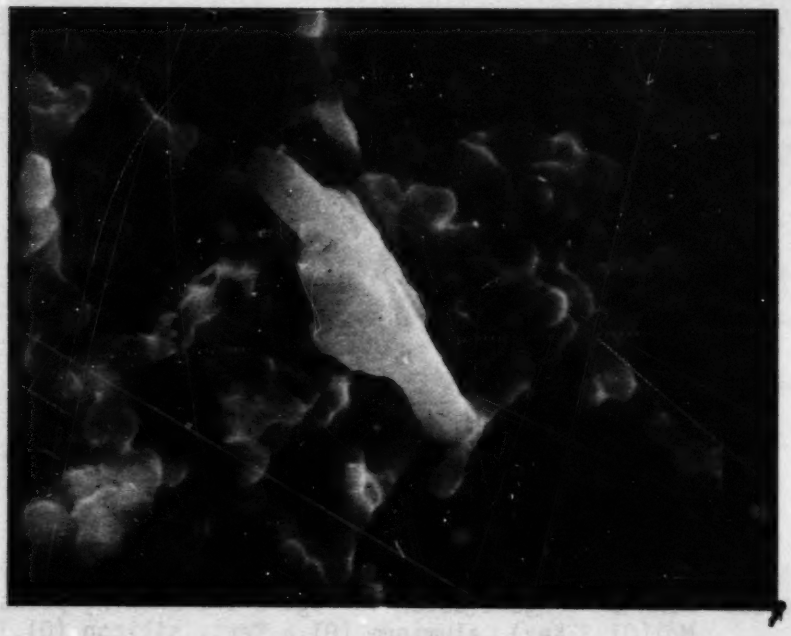

Figure 20. SEMG of calcium sulfate, elongated prism (5.5 µm x 0.7 µm) with an attached mineral flake containing silicon, magnesium, sodium and potassium; 8,000X.

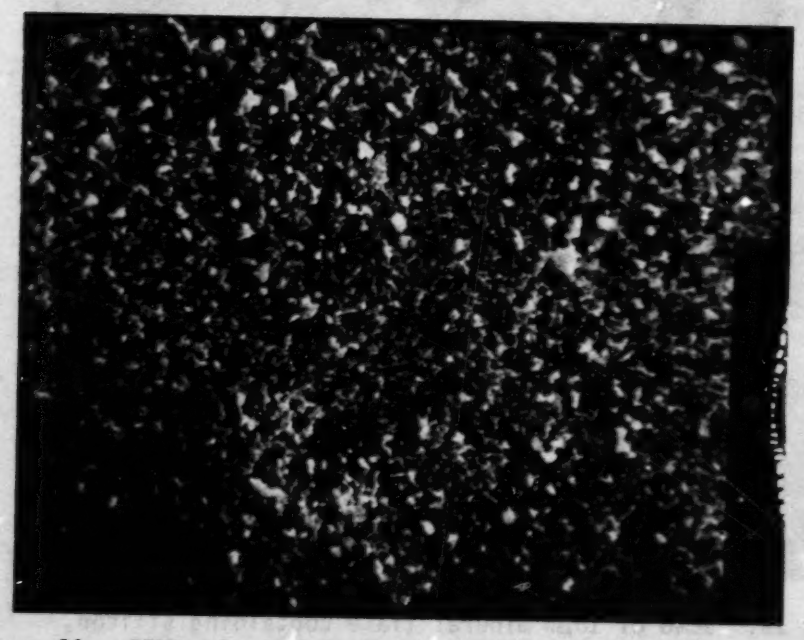

Figure 21. SEMG of sample no. 5, showing the greatest aerosol concentrations among samples 1-5. Most of the particles are mineral fragments; 500X.

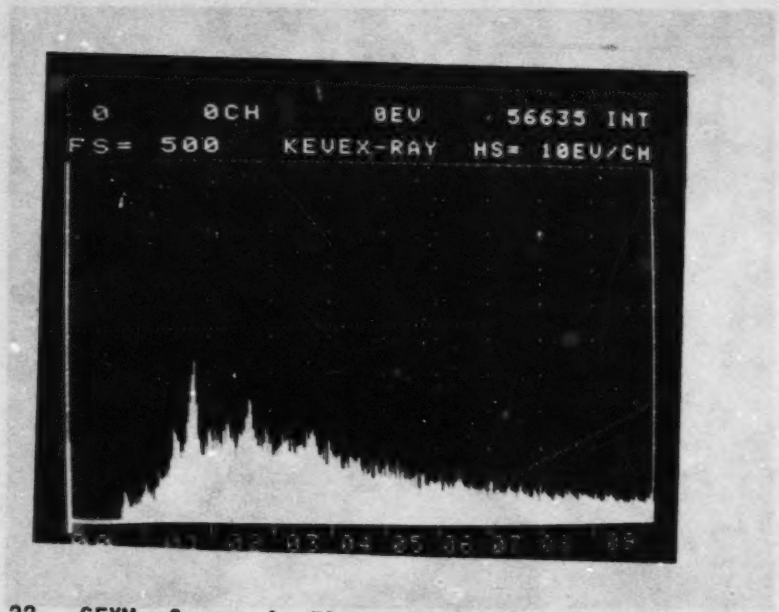

Figure 22. SEXM of area in Figure 21 showing peaks for sodium (01.1 Kev), aluminum (01.5 Kev), silicon (main peak, 01.7 Kev), sulfur (02.3 Kev).

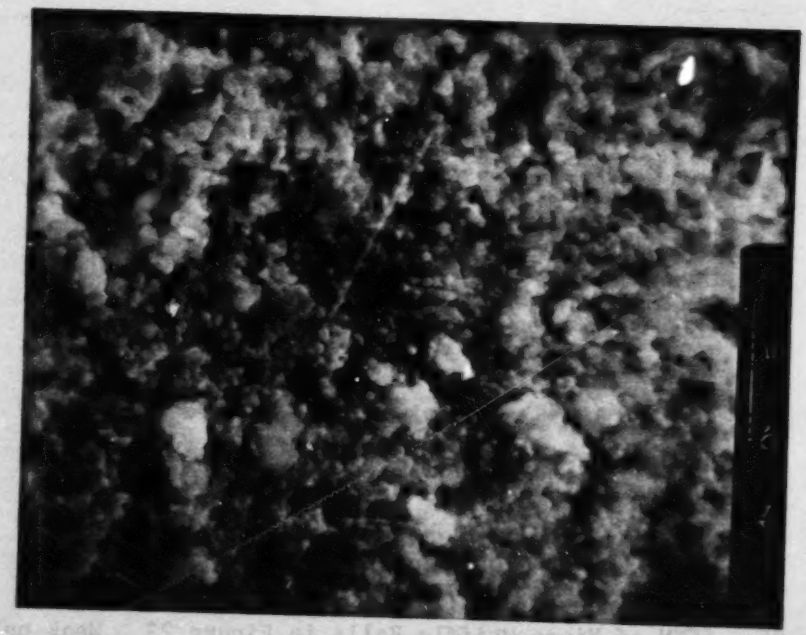

Figure 23. SEMG of small, dark deposit appearing as a hole in Figure 21; 3,000X.

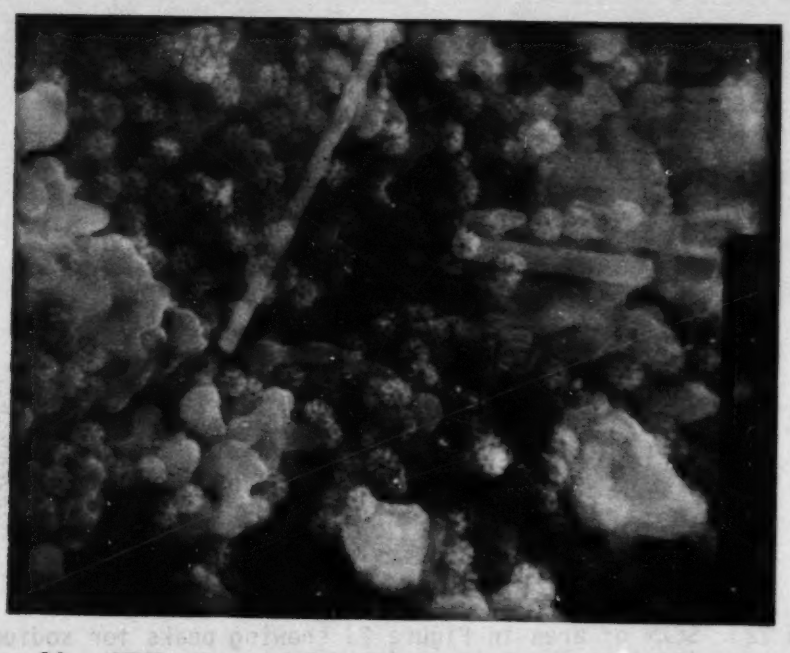

Figure 24. SEMG of particles in Figure 22 showing numerous 0.4 µm Micro Whiffle Balls and calcium alumino silicate needles; 10,000X.

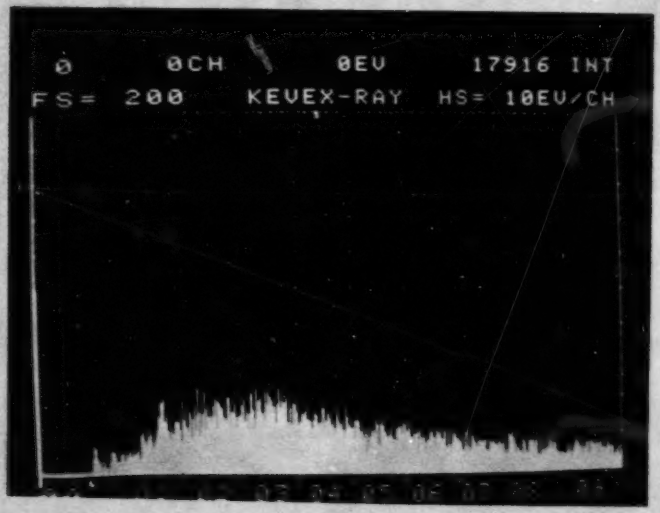

Figure 25. SEXM of Micro Whiffle Balls in Figure 23. Weak peaks for aluminum and silicon are from the silicate needles shown in Figure 23.

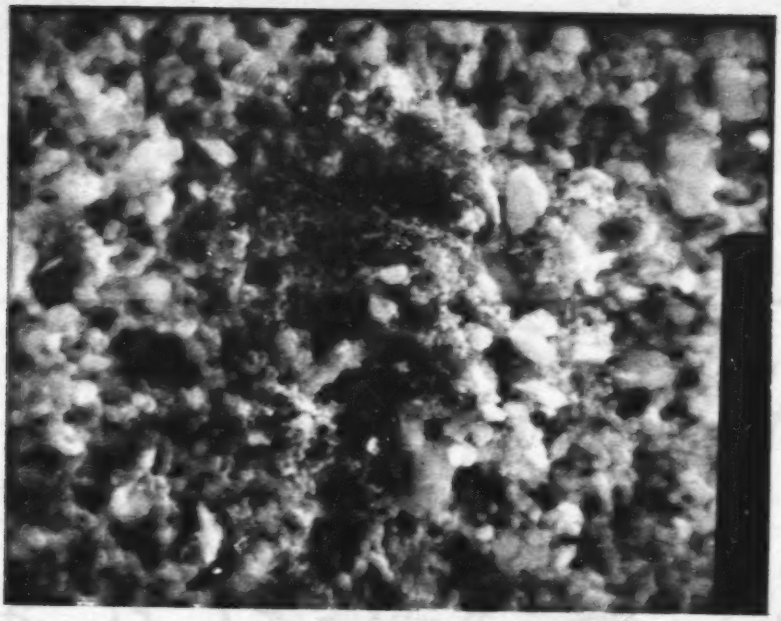

Figure 26. SEMG of carbonaceous agglomerate (probably auto exhaust) in sample no. 5; 3,000X.

Figure 27. SEMG of sample no. 5 showing unusual agglomerate (perhaps aggregate) in the center of the photo. The upper, right portion of the duo contains lead and bromine (probably $PbBr_2$) while the lower left portion contains magnesium, aluminum and silicon.

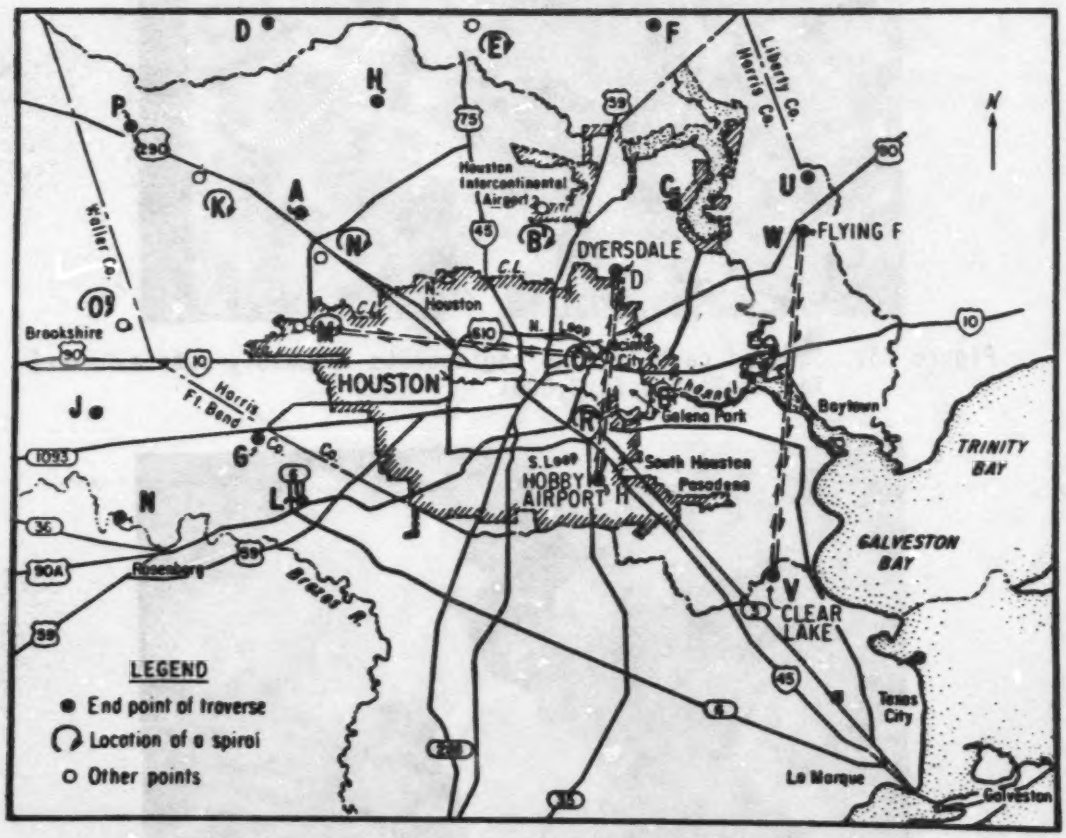

Figure 28. Flight paths for 20 July 1974 sampling mission.

Figure 29. Photomicrograph of sample no. 6, showing a low concentration of particles that are principally minerals; crossed polars, 406X.

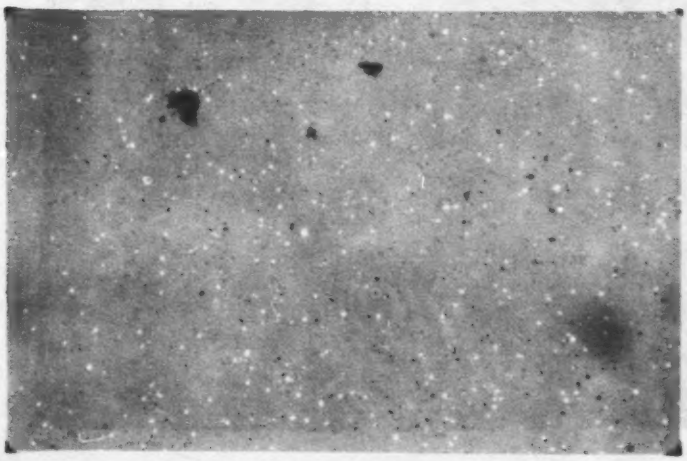

Figure 30. Photomicrograph of sample no. 7, showing predominantly mineral fragments (bright) plus a few clusters of carbonaceous agglomerates (black); polars uncrossed 20°, 163X.

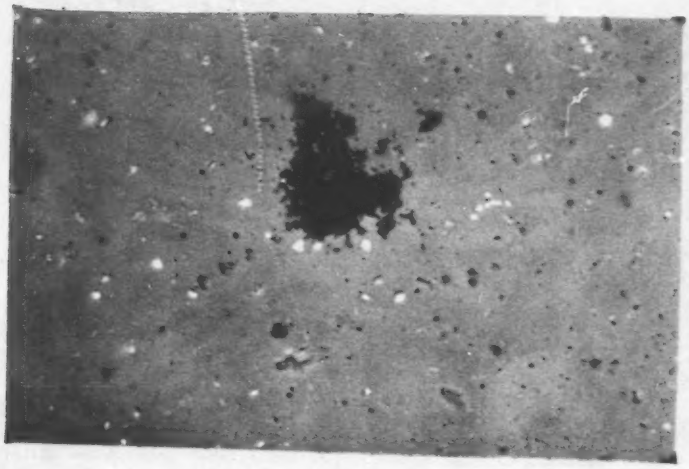

Figure 31. Photomicrograph of large, carbonaceous cluster shown in Figure 30, polars uncrossed 20°, 652X.

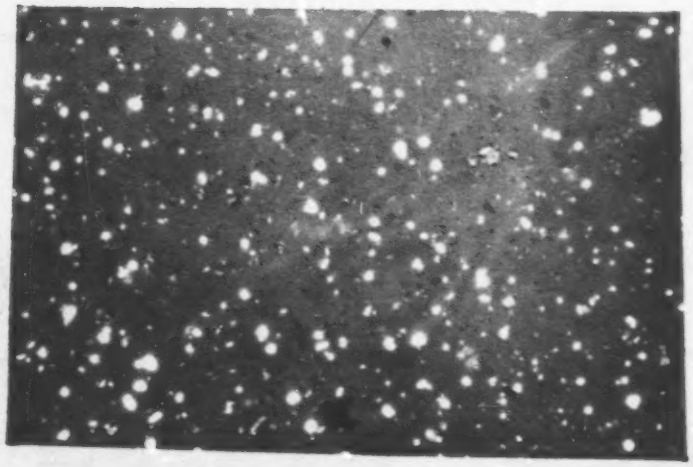

Figure 32. Photomicrograph of sample no. 8, showing a moderate concentration of minerals plus a few carbonaceous clusters; polars uncrossed 10°, 406X.

Figure 33. Photomicrograph of sample no. 9, showing moderate concentration of minerals plus a trace of opaque, carbonaceous agglomerates on the filter as received; reflected light, 65X.

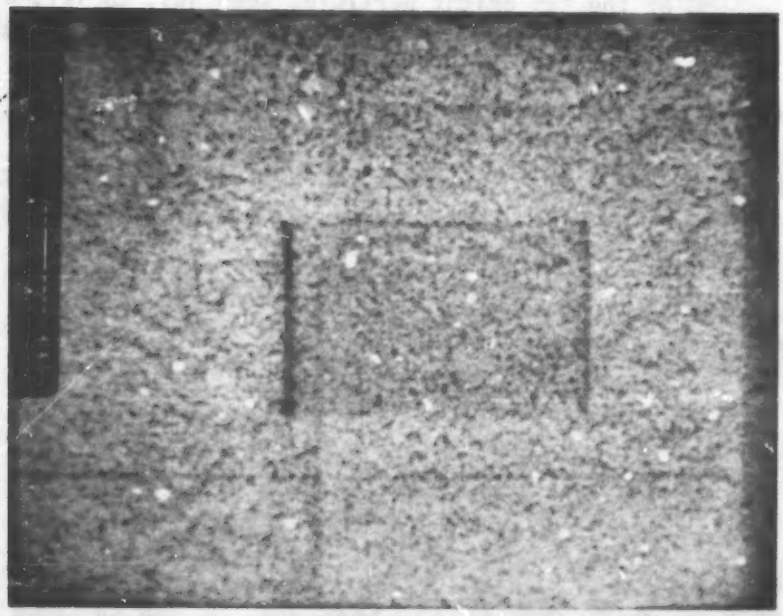

Figure 34. Micrograph of sample no. 6 taken with back scattered electrons that show increasing brightness with increases in atomic weight; 300X.

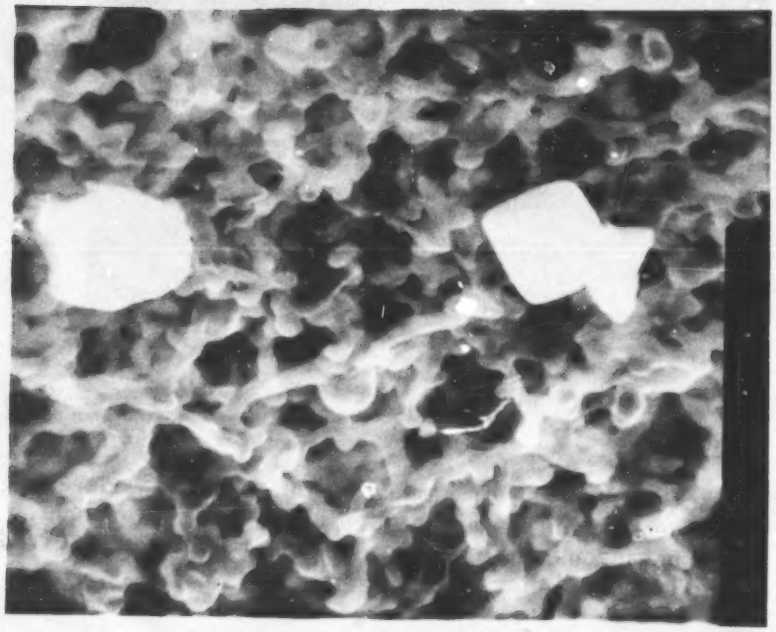

Figure 35. SEMG of the two bright particles seen just to left of center in Figure 34. Both particles are sodium chloride, probably sea spray; 6000X.

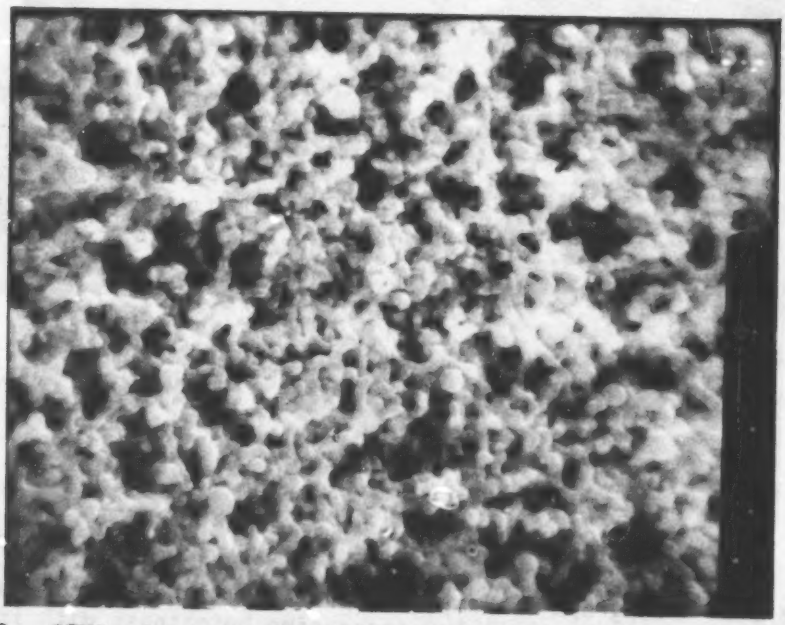

Figure 36. SEMG of sample no. 6 showing artifact spheres from the filter; 3,000X.

Figure 37. SEMG of sample no. 7 showing area of moderate mineral concentration along with a few carbonaceous clusters; 100X.

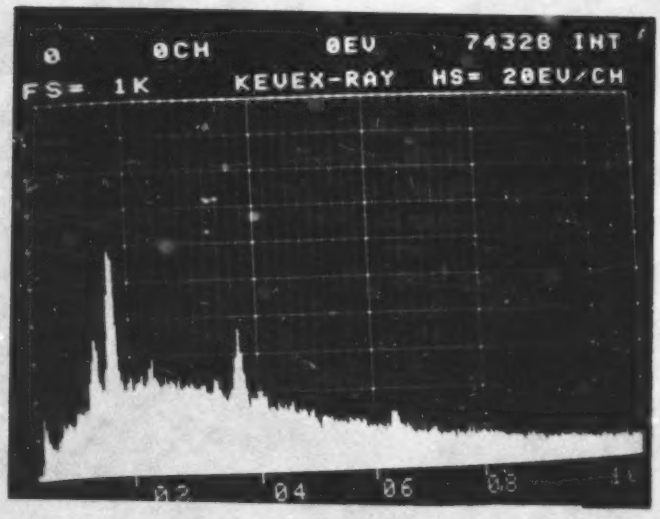

Figure 38. SEXM of area in Figure 37 showing major peaks for aluminum, silicon and calcium.

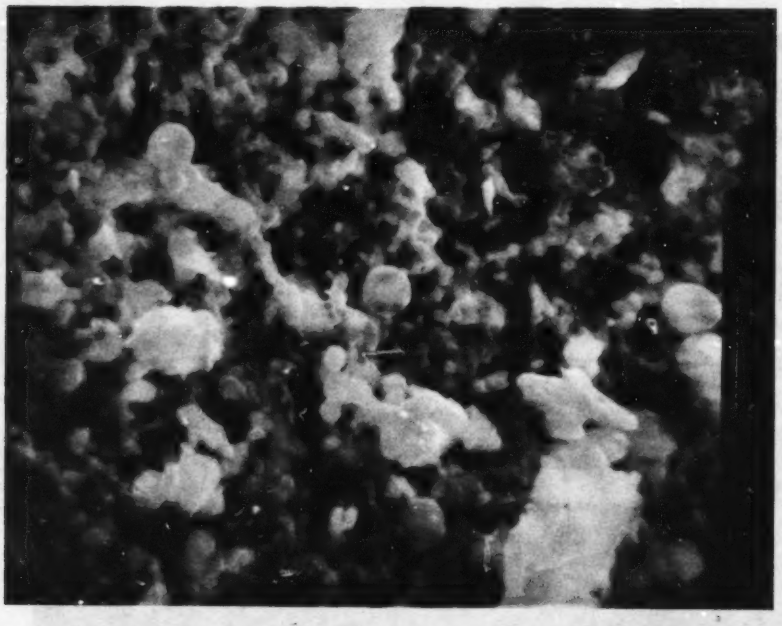

Figure 39. SEMG of sample no. 7 showing mineral fragments and artifact spheres; 3,000X.

Figure 40. SEMG of alumino silicate mineral sliver seen in upper right quadrant of Figure 39; 20,000X.

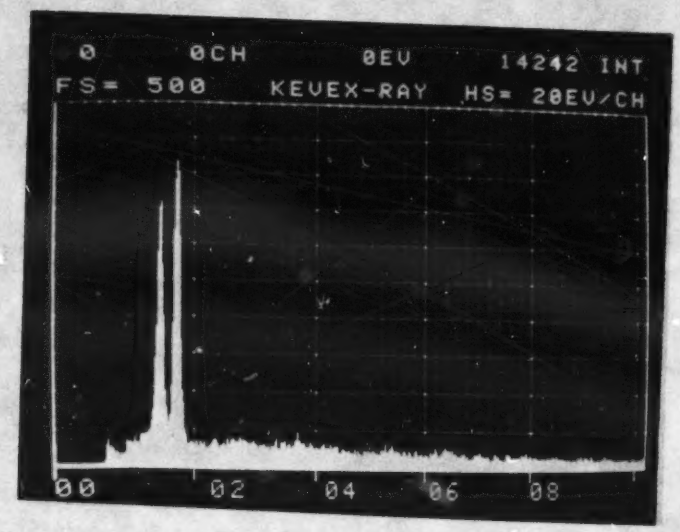

Figure 41. SEXM of Mineral sliver in Figure 40 showing major peaks for aluminum and silicon.

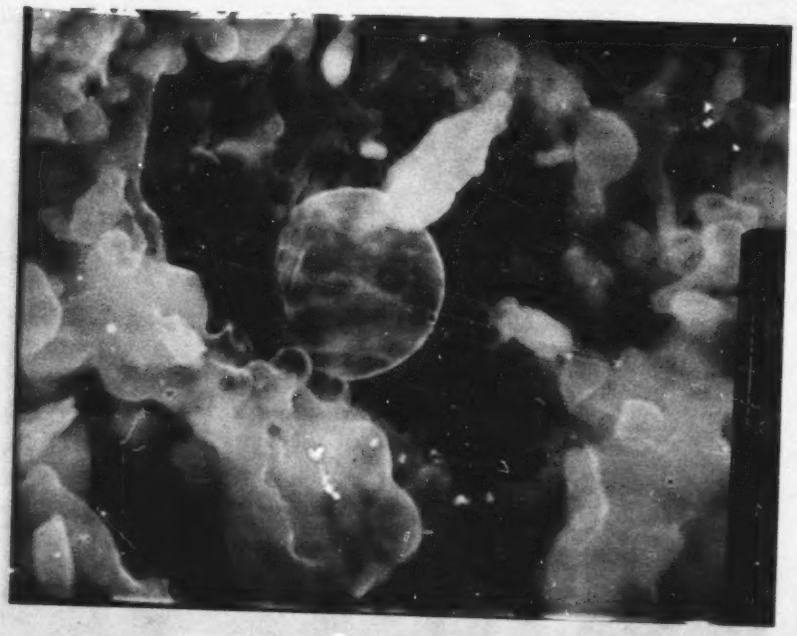

Figure 42. SEMG of artifact sphere seen in upper right corner of Figure 39; 10,000X.

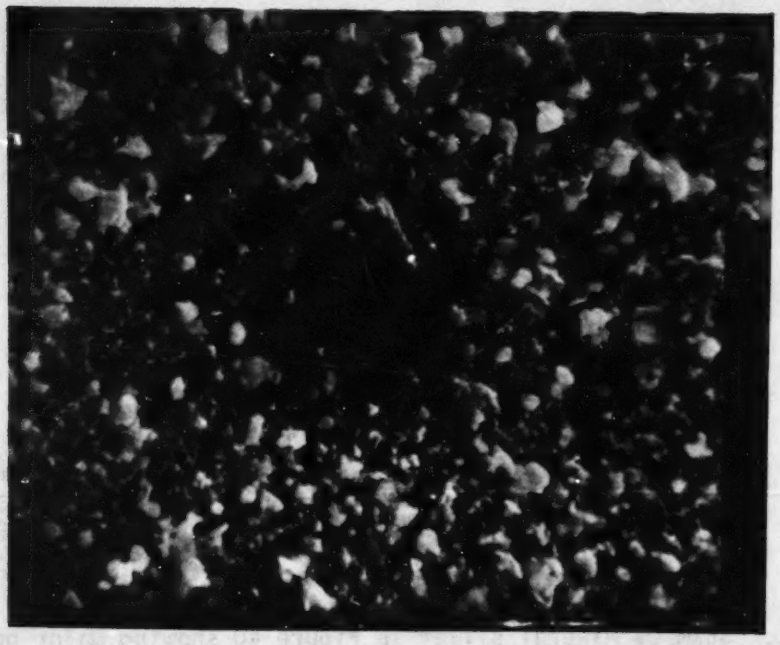

Figure 43. SEMG of sample no. 7, showing black, carbonaceous cluster; 1,000X.

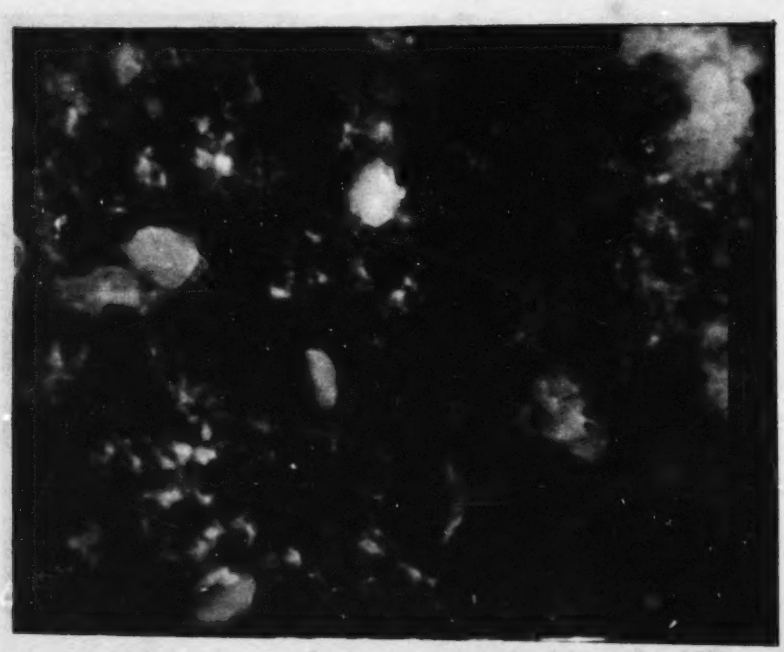

Figure 44. SEMG of black, carbonaceous cluster in Figure 43; 10,000X.

Figure 45. SEMG of thin mineral fragments of sample no. 7. Particle A is an alumino silicate, particle B contains only silicon (probably quartz) and particle C contains sodium, magnesium, aluminum, silicon, sulfur, potassium, calcium, and iron; 10,000X.

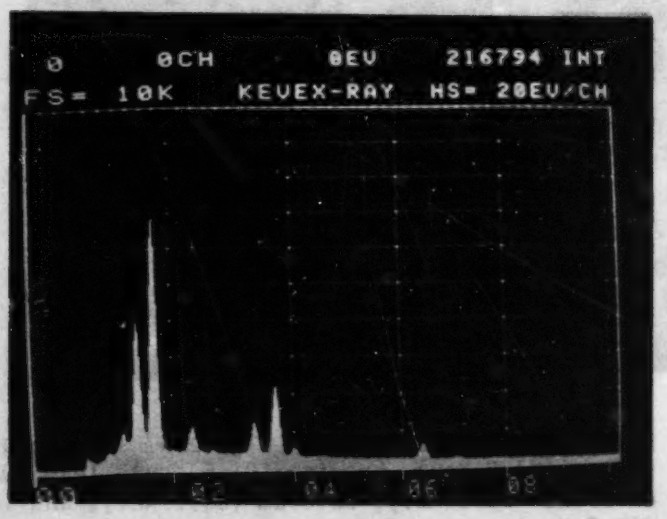

Figure 46. SEXM of particle C in Figure 45.

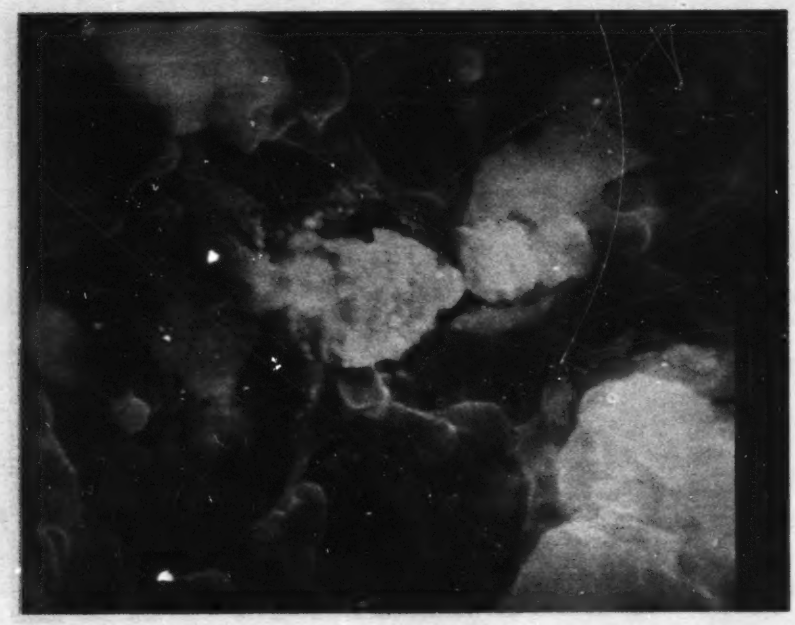

Figure 47. SEMG of lead chloro bromide particle in center of photo, from sample no. 7; 10,000X.

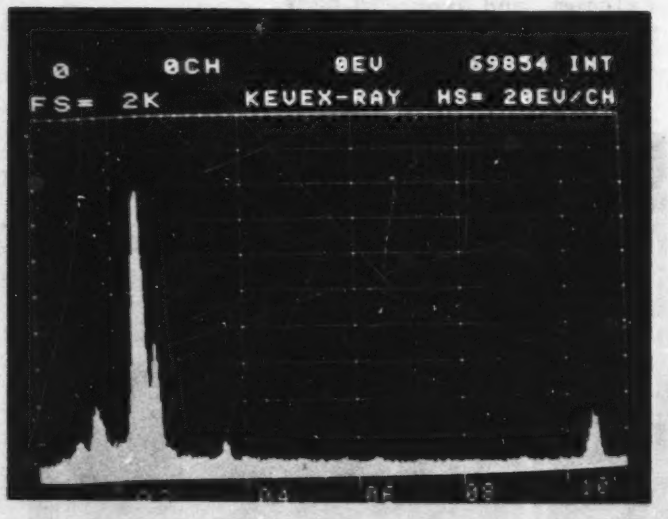

Figure 48. SEXM of PbClBr particle in Figure 47 showing peaks for sodium (01.0 Kev), bromine (01.5 Kev), lead (02.4 Kev), chlorine (02.6 Kev), calcium (03.7 Kev), and lead (10.5 Kev).

Figure 49. SEMG of large (3 μm) lead bromide particle on sample no. 7; 10,000X.

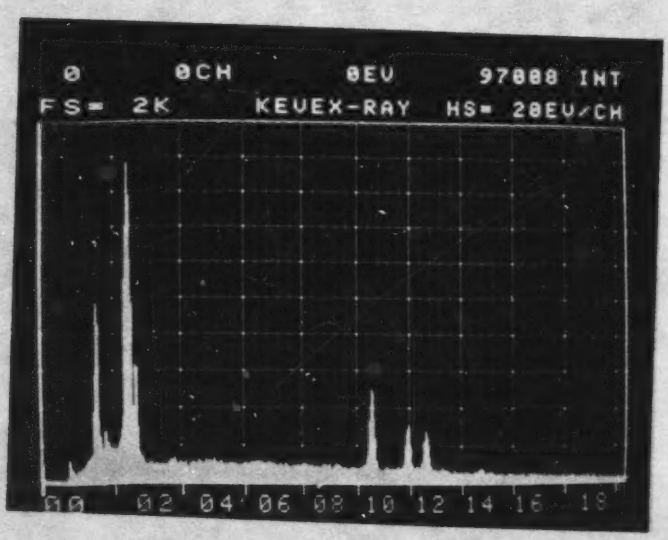

Figure 50. SEXM of lead bromide particle in Figure 49; compare with Figure 48.

Figure 51. SEMG of sample no. 7, showing artifact spheres. The filter area photographed is outside the central aerosol deposit; 3,000X.

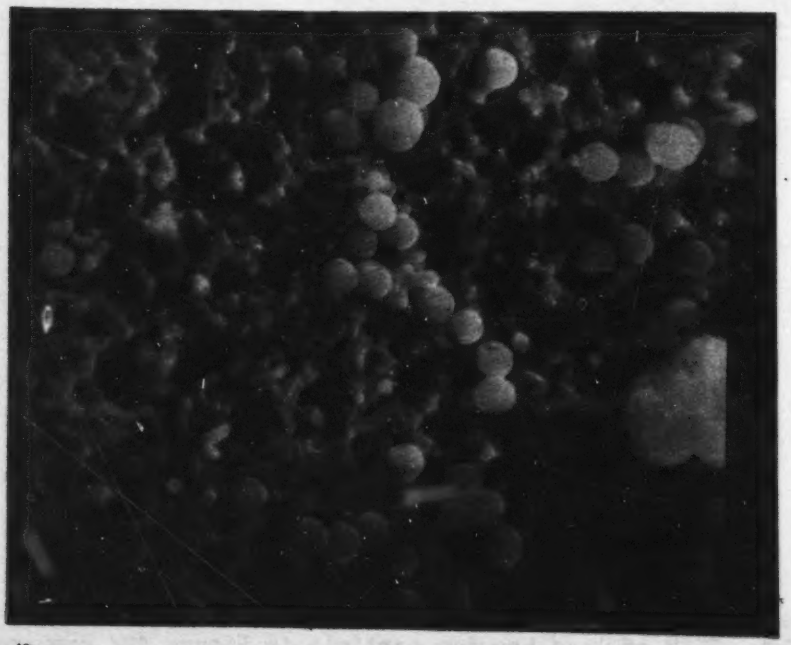

Figure 52. SEMG of sample no. 7, near the outer filtration periphery showing artifact spheres; 3,000X.

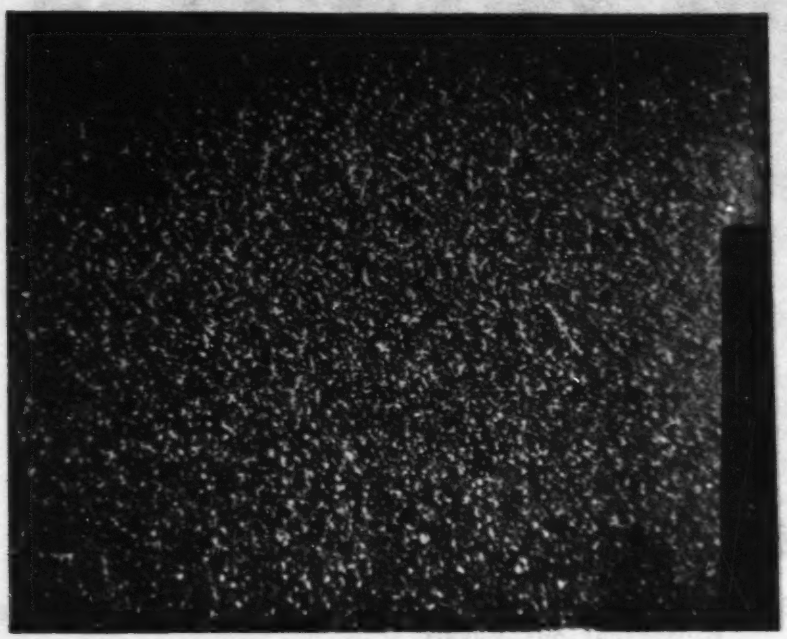

Figure 53. SEMG of highest aerosol concentration on sample no. 8, 100X.

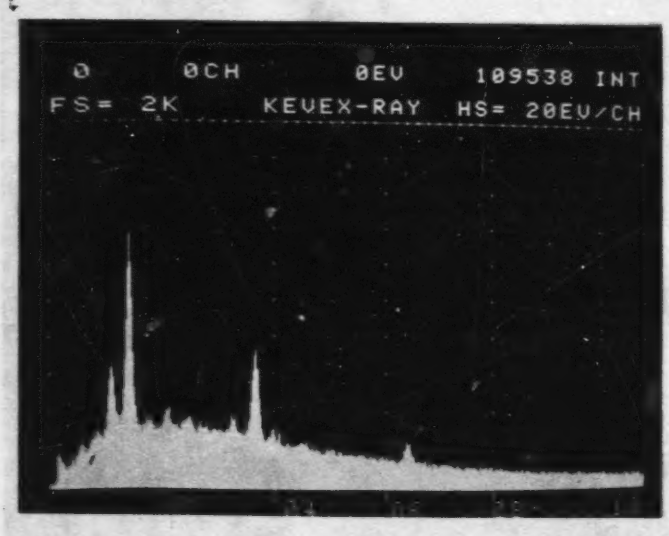

Figure 54. SEXM of filter area shown in Figure 53. The peaks correspond with sodium (01.0 Kev), magnesium (01.3 Kev), aluminum (01.5 Kev), silicon (01.7 Kev), sulphur (02.3 Kev), chlorine (02.6 Kev), potassium (03.3 Kev), calcium (03.7 and 04.0 Kev) and iron (06.4 Kev).

Figure 55. SEMG showing portion of area in Figure 53, at higher magnification; 1,000X.

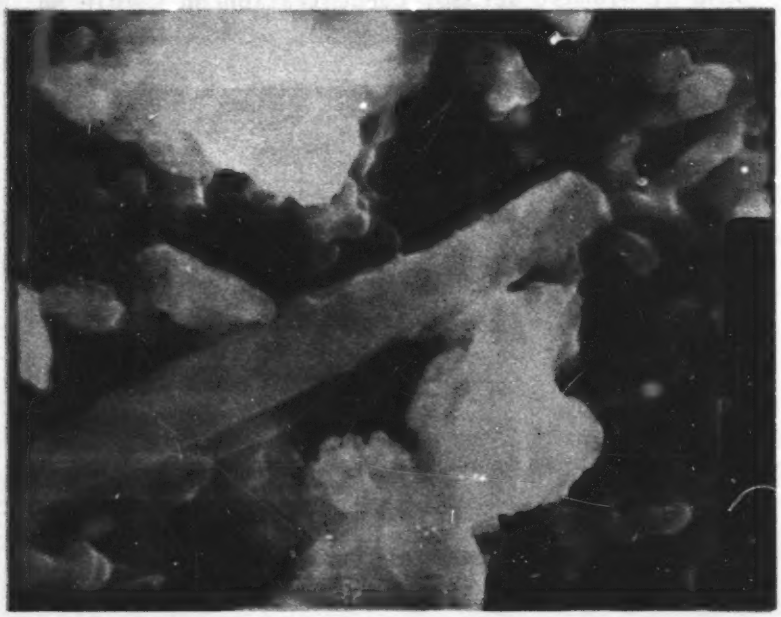

Figure 56. SEMG of mineral needle (or flake on edge) from sample no. 8; 10,000X.

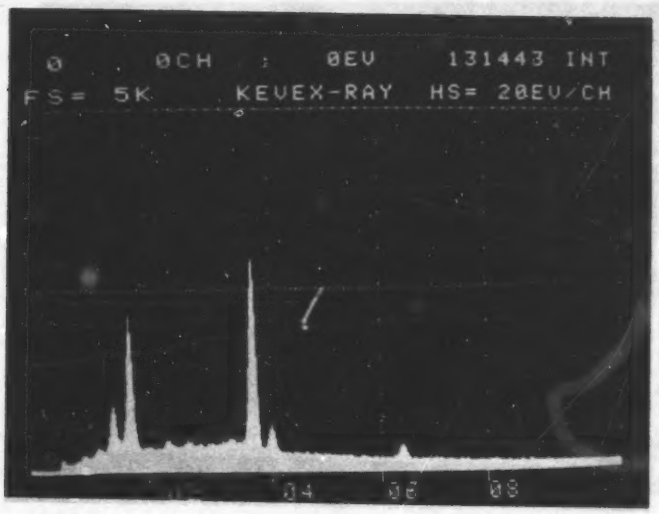

Figure 57. SEXM of mineral needle in Figure 56 showing principal peaks for Al, Si and Ca. The adjacent particles maybe also contributing to this spectrum.

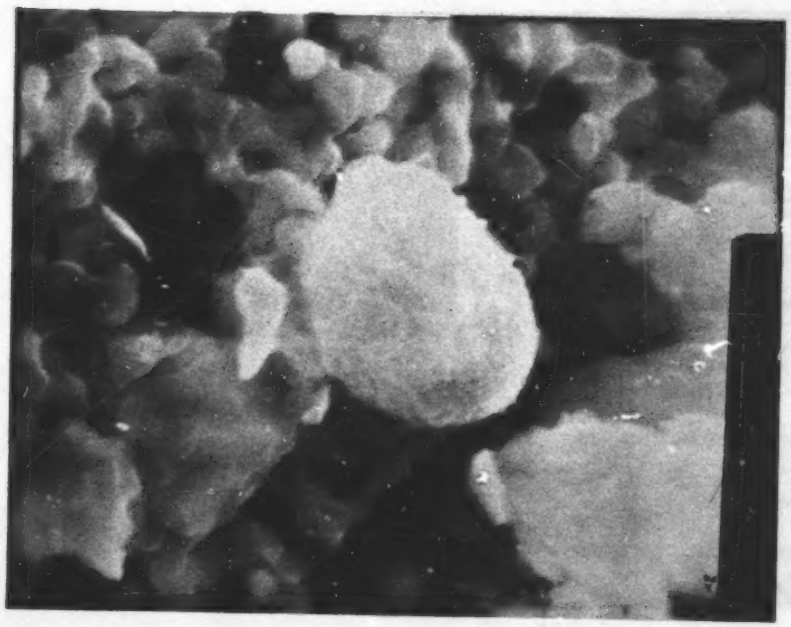

Figure 58. SEMG of rounded mineral grain in sample no. 8 containing calcium as the major constituent (probably calcite); 10,000X.

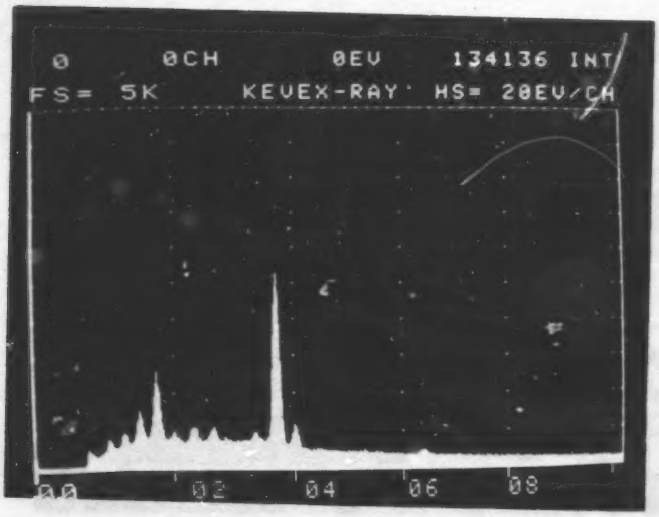

Figure 59. SEXM of rounded mineral grain showing peaks for Na, Mg, Al, Si, P, S, Cl, K, Ca and Fe. The nearby mineral grains are also contributing to the spectrum.

Figure 60. SEMG of cubic crystal, probably Na_2CO_3 from sea spray, on sample no. 8, 10,000X.

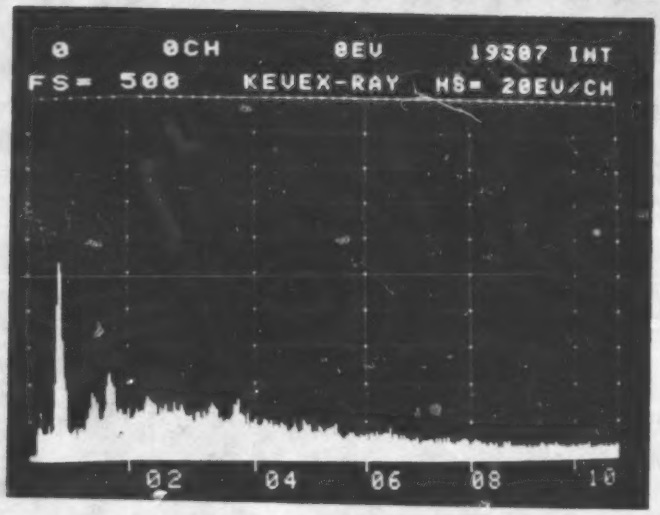

Figure 61. SEXM of cubic crystal showing a major peak for sodium with minor peaks for aluminum, silicon, sulfur, potassium and calcium. The peaks other than sodium are due to the adjacent particle.

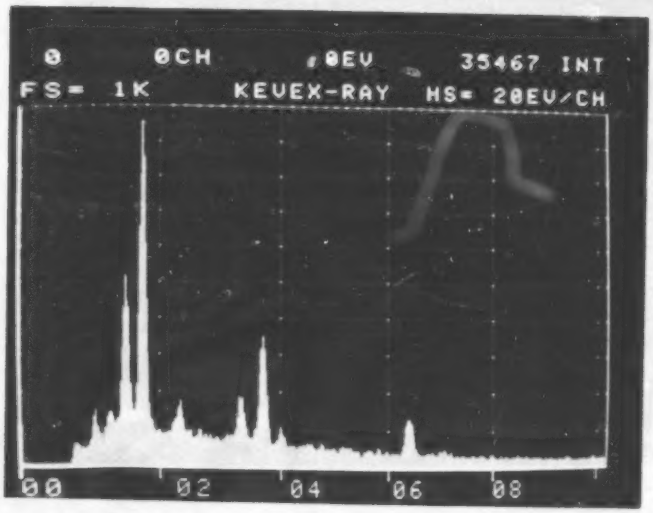

Figure 62. SEXM of particle attached to cubic crystal in Figure 61.

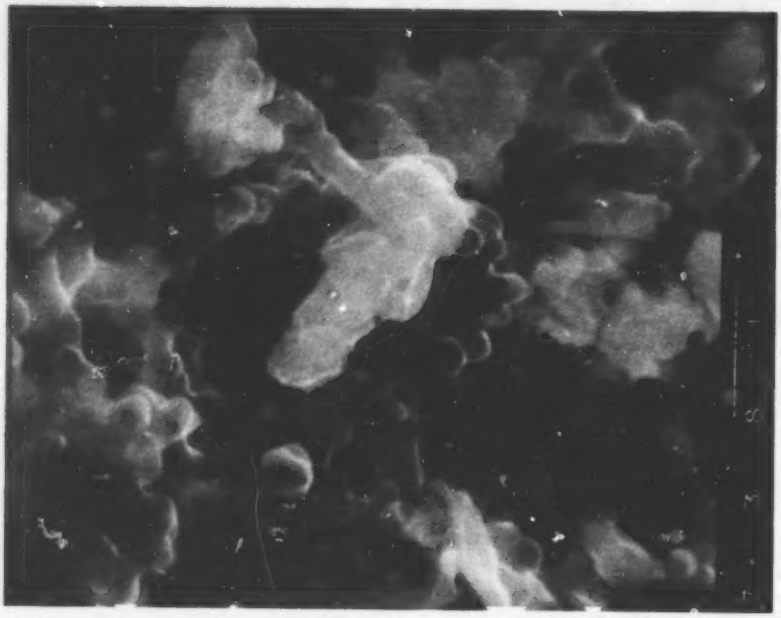

Figure 63. SEMG of calcium alumino silicate mineral grain from sample no. 8; 10,000X.

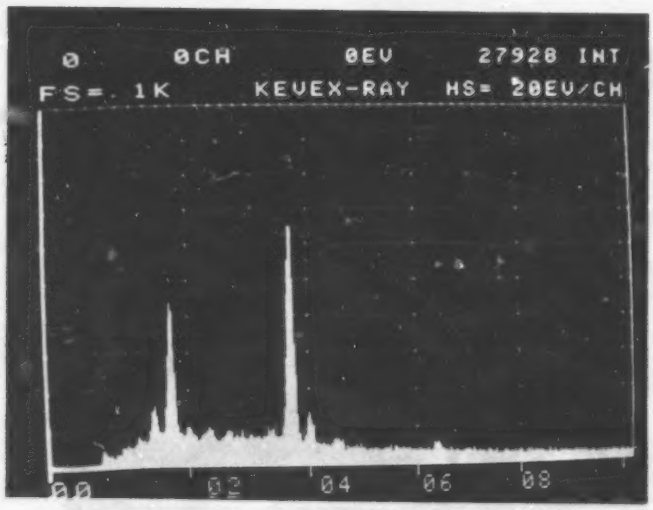

Figure 64. SEXM of silicate mineral in Figure 63 with major peaks for Al (01.5 Kev), Si (01.7 Kev), and Ca (03.7 and 04.0 Kev.)

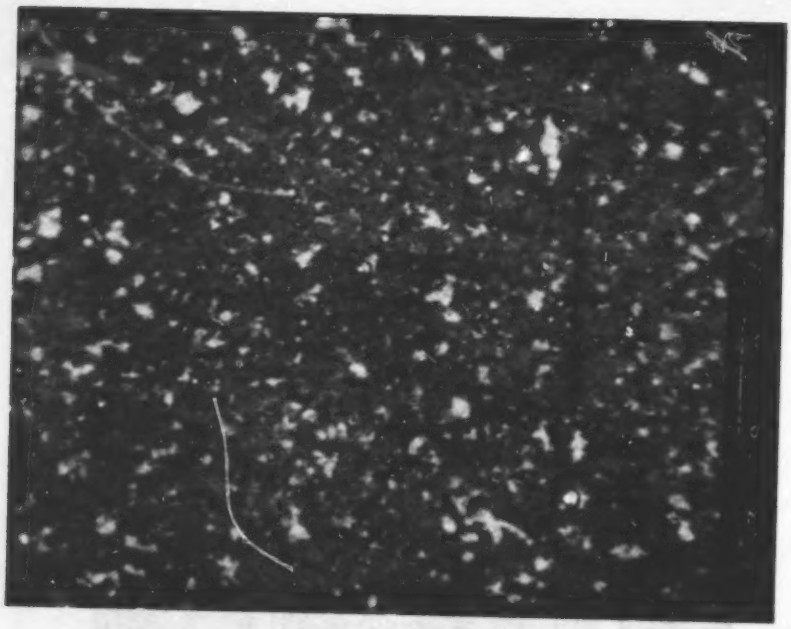

Figure 65. Back scattered electron image to detect heavy metals, especially lead in sample no. 8. The five small, very bright dots that are circled are lead compounds from auto exhaust; 500X.

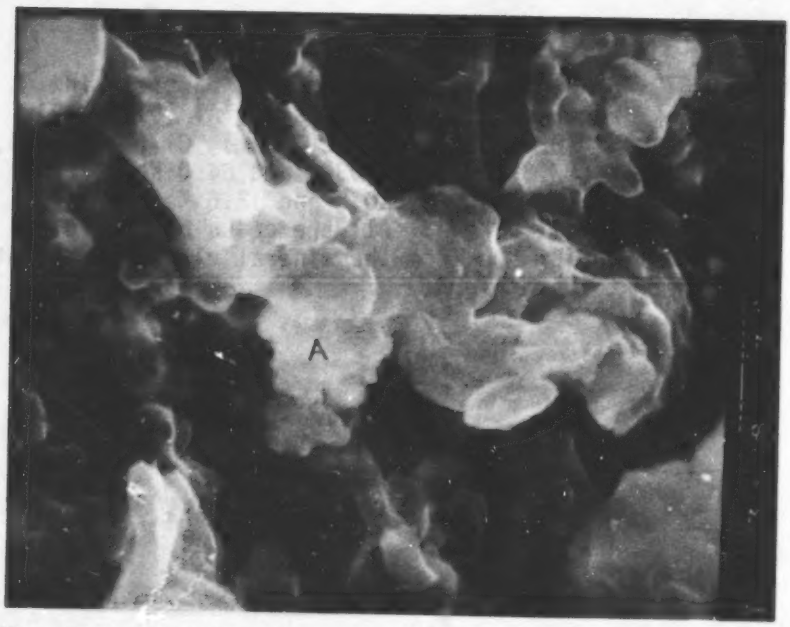

Figure 66. SEMG of lead chloro bromide particle marked A adjacent to a mineral fragment of sample no. 8; 10,000X.

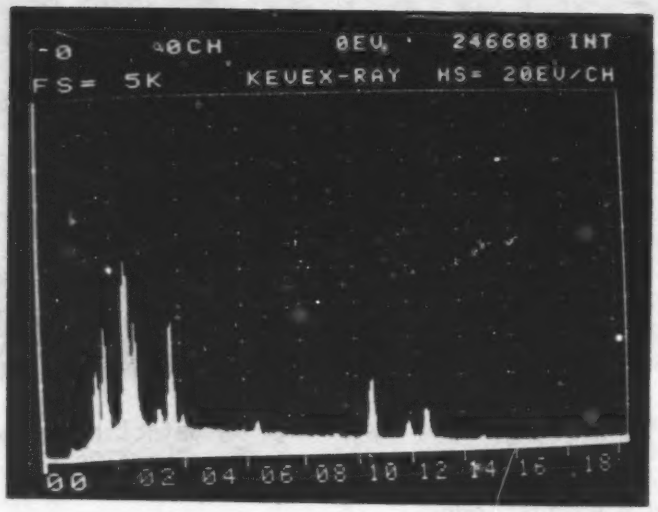

Figure 67. SEXM of lead chloro bromide particle in Figure 66 showing peaks for Al (01.5 Kev), Si (01.7 Kev), Pb (02.3 Kev), Cl (02.6 Kev), K (03.3 Kev), Ca (03.7 and 04.0 Kev), Fe (06.4 Kev), Pb (10.5 and 12.6 Kev) and Br (11.9 Kev). All the peaks but Pb, Cl and Br are from the mineral cluster adjacent to particle A.

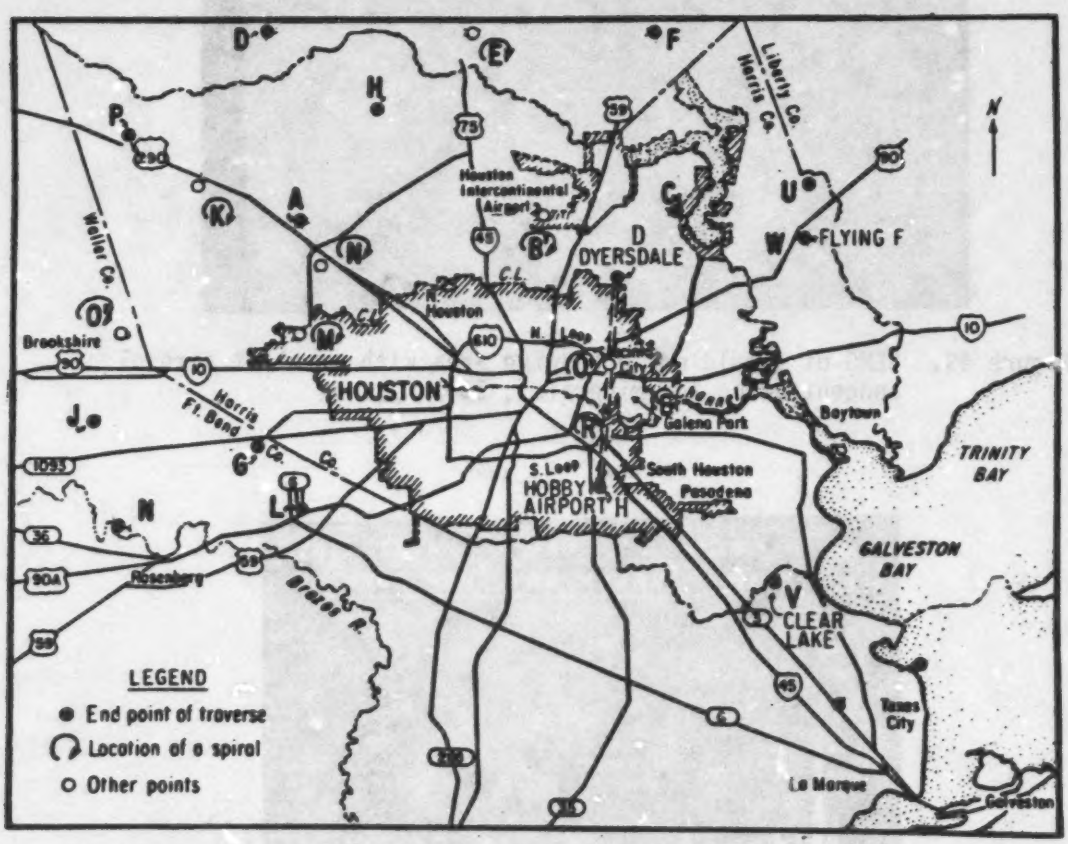

Figure 68. Flight path for 21 July 1974 sampling mission.

Figure 69. SEMG of sample no. 9 showing area with greatest aerosol concentration (of minerals); 100X.

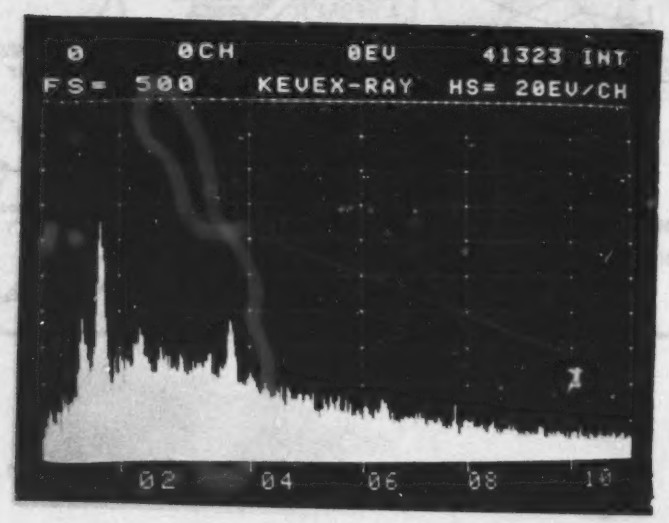

Figure 70. SEXM of area shown in Figure 69 with prominent peaks for Al, Si, S, and Ca.

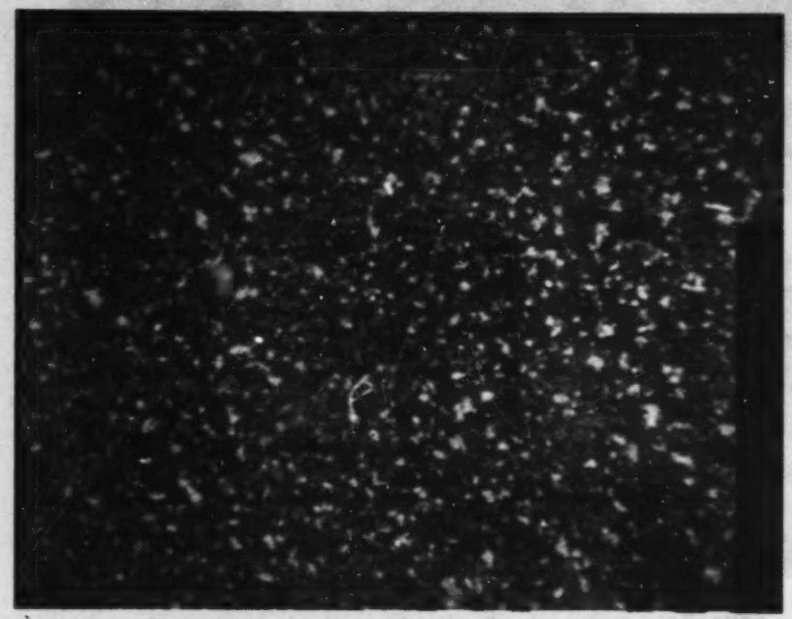

Figure 71. Back scattered electron image of central area in Figure 69 showing the prescence of lead compounds from vehicle exhaust as small bright dots. The diaphanous, rectangular particle at the center is a moth scale; 300X.

Figure 72. SEMG of sample no. 9 showing a PbClBr particle at the center; 10,000X.

Figure 73. SEMG of sample no. 9 showing angular mineral grains covered by a fine, carbonaceous agglomerate; 10,000X.

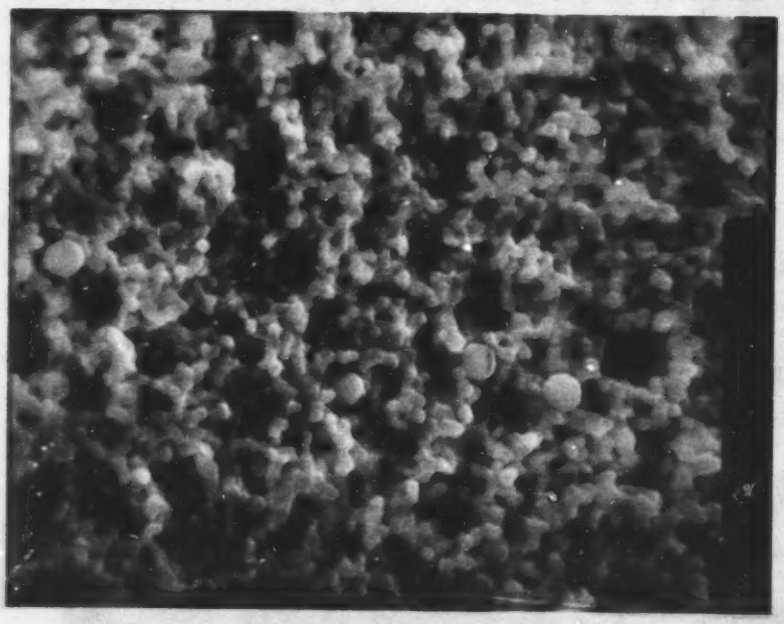

Figure 74. SEMG of artifact spheres in sample no. 9; 3,000X.

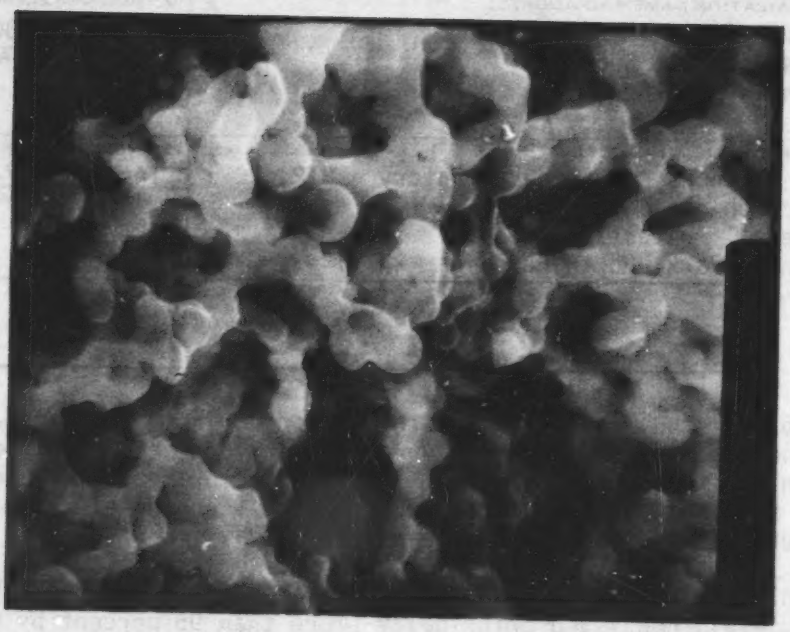

Figure 75. SEMG showing artifact spheres from a sample collected in Texas City, Texas on 24 July 1974; 10,000X.